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TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. XIV.—1897-98.

EDITED BY M. WALTON BROWN, SECRETARY.

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1898.

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TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, AUGUST 12TH, 1897.

MR. JAMES HASTIE, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. THOS. D. LAWTHER, Calder Ironworks, Coatbridge.
Mr. ALEX. R. MILLIGAN, Milnwood Colliery, Bellshill.

ASSOCIATE MEMBER—

Mr. KARL KRICKHAUS, P.O. Box 2098, Johannesburg, South Africa.

STUDENT—

Mr. DAVID TODD, 144, Almada Street, Hamilton.

The discussion of the Council's "Report on the Home Secretary's Explosives in Coal-mines Order, 1896," was closed, and a vote of thanks was given to the Council.

Mr. A. F. HARGREAVES read the following paper on "High-grade Gunpowder":—

HIGH-GRADE GUNPOWDER.

By A. F. HARGREAVES.

It must be acknowledged that the question of the continued use of gunpowder in mines is to be determined, not from the manufacturer's point of view, but entirely from its measure of safety and its general utility. These points are best and most satisfactorily ascertained from the statistics of the past, to which reference will be made, although the primary object of this paper is to give reasons for the recommendations which have been made to the Home Secretary, that gunpowder of a high quality or standard, which the Gunpowder Trade Association has very properly termed "high-grade gunpowder," may be placed on the list of permitted explosives for use in coal mines.

In order, however, that the advantages of using a high-grade powder may be recognized, it may be well to refer to the recent history of the subject, and particularly to the statistics of mortalities due to explosives in coal-mines prepared by Mr. Donald M. D. Stuart, and published by the Gunpowder Trade Association.

What the writer hopes to show is, firstly, that gunpowder, even as at present in use, with its varied and uncertain dynamical powers, and in many cases objectionable features, has a high degree of safety when compared with other explosives; and, secondly, how this degree of safety may be still further increased by the enforcement of suitable regulations for all gunpowders used in coal-mines being of a definite and of a high quality.

When the question of explosives in coal-mines came prominently to the front, and their action was considered by the North of England Institute of Mining and Mechanical Engineers and the Royal Commission on Explosions from Coal-dust in Mines in 1894, it was undoubtedly the case that before this Commission the opponents of gunpowder, though few in number, had almost, with one or two exceptions, everything their own way. Messrs. H. Hall and J. S. Martin, two of H.M. inspectors of mines, were strongly in evidence, giving results of a number of experiments of a damaging character so far as gunpowder was concerned.

Eminent colliery managers and mining engineers were examined, and strong opinions were expressed by them as to the general utility and safety of gunpowder, but it is to be regretted that not a single explosives expert with an intimate knowledge of gunpowder and capable of testing and weighing the trustworthiness of Mr. H. Hall's experiments was examined. This was unquestionably a great mistake, but probably it arose from a feeling of the impregnable position which gunpowder had so long maintained.

It is, however, somewhat remarkable that the Royal Commissioners, having thus heard everything against black-powder and little in its favour, and notwithstanding the fact that considerable weight was given to many experiments and statistics which are now known to be unreliable so far as experiments are concerned, and inaccurate so far as the statistics are concerned, did not feel justified in recommending the universal abolition of gunpowder, but thought that its use might be continued, even in dry and dusty parts, provided a sufficient and effectual method of watering the dust is systematically carried out.

For some considerable time prior to the Royal Commission, Mr. H. Hall, had agitated this question, he had been a strong advocate for the total prohibition of gunpowder, and strongly recommended the sprengel class of explosives, notably roburite. These were at first distinctly put forward as flameless, and for a time it looked as if they were about to carry all before them.

The exhaustive and valuable series of experiments made by the North of England Institute of Mining and Mechanical Engineers proved the non-flamelessness of these explosives, and they were then denominated "safety-explosives."

Mr. H. Hall stated, in his report to the Home Secretary for 1892, that from the years 1873 to 1892 about 2,000 deaths were caused by explosions in coal-mines, but actually there have been 664, a difference of 1,336. Mr. Stuart says that an examination of Mr. Hall's figures shows that explosions caused by candles, lamps, and high explosives such as gelatine, dynamite, gelignite, roburite, tonite, and securite, are charged against gunpowder. These are a few examples of Mr. Hall's figures, which, coming from an inspector of mines, have naturally had the effect of leading the public to regard gunpowder as a real *bête noire*, and as dark in character as it is black in colour.

But the truth has gradually been evolved, and of the millions of shots fired annually in the coal-fields of Great Britain, there are reliable figures which indicate that at the very least 90 per cent. of these shots are

those of gunpowder, and that the remaining 10 per cent. may be divided amongst the various high explosives. It is somewhat startling to find that the 10 per cent. of the high explosives used have, during the last four years, caused 25·33 per cent. of the total deaths in handling, and 69·66 per cent. of the total deaths in shot-firing, and this is the period during which the so-called "safety explosives" have been most prominently brought to the front.

Mr. H. Baldwin in his preface to Mr. Stuart's report on *Explosives in Coal-mines*, published with the authority of the Gunpowder Trade Association, states :—

Mr. A. H. Stokes, H.M. inspector of mines. has stated that 2,000,000 shots are fired annually in the Midland district.* In the last twenty-five years (1872-1896) there has been only one fatal explosion (causing the loss of 7 lives) ; in other words, one death for each 7,000,000 shots (round figures), or one shot causing explosion in 50,000,000 fired. In the same district, not one life was lost in handling gunpowder during the last three years (1894, 1895, and 1896), though not less than 5,500,000 shots of this explosive were fired, while in 1896, the 10 per cent. of high explosives caused over 45 per cent. of the personal mutilations (non-fatal).†

Prof. Merivale, of the Broomhill collieries, Northumberland, has stated that in the last twenty-five years 7,700,000 shots have been fired in these collieries without loss of life.

Mr. H. Richardson, of the Ashington and Backworth coal companies, where over 2,000,000 tons of coal are raised annually, and gunpowder exclusively employed, has known of no personal injury caused by the ignition of gas or dust from shot-firing in these mines during the last thirty-six years.

It would be impossible to produce more emphatic evidence in favour of the retention of gunpowder, whilst it is remarkable that where high explosives have been introduced with a view to supposed greater safety, disasters have frequently followed. For example :—

Mr. F. Wardell, H.M. inspector of mines for Yorkshire, in reporting upon the Thorncliffe explosion in 1890, stated that roburite, which had been introduced in place of gunpowder about eighteen months previously, caused the explosion ; adding, "The adoption of roburite by the company in lieu of gunpowder had been with a view to increased safety."‡ For the preceding seventeen years gunpowder had been exclusively used in this mine with immunity from explosion.

Mr. W. N. Atkinson, H.M. inspector of mines for North Staffordshire, reporting upon the Apedale explosion, stated that it was caused by gelignite, which, with roburite, had four months previously been substituted for gunpowder.§ Gunpowder had been used for the previous twenty-two years without causing any explosion.

* *First Report of the Royal Commission on Explosions from Coal-dust*, questions 3,070 and 3,072.

† *Report of H.M. Inspector of Mines for the Midland District*, 1896, page 9.

‡ *Report of H.M. Inspector of Mines for the Yorkshire District*, 1890, pages 16 and 17.

§ *Report of H.M. Inspector of Mines for the North Staffordshire District*, 1891, page 11.

At the Tylorstown colliery, South Wales, gunpowder had been in use up to 1894, and no explosion had ever occurred. Ammonite and bellite were then substituted, and a disastrous explosion happened in January, 1896, which Mr. J. T. Robson, H.M. inspector of mines, reported was due to a shot of ammonite. *

In the face of these facts, Mr. H. Hall makes the following statement in his report for 1896 to the Home Secretary:—"Gunpowder should be treated as the miner's greatest enemy, and never allowed to go into a colliery."

The foregoing statements refer to gunpowders as at present made and used. It will now be shown what is the varying character of the gunpowers which are to-day manufactured, sold, and used.

The following figures are results of testing samples of gunpowder collected impartially from all parts of Great Britain. They were not collected especially for this enquiry, but are excerpts from an ordinary laboratory test-book, and no doubt all gunpowder-makers have similar records. They were tested in an ordinary military mortar of 8 inches calibre, with a 68 pounds ball. Two ounces of each sample of gunpowder were placed in the mortar, fired, and the distance in feet measured to which the ball was projected, each record being an average of 3 experiments:—61, 120, 49, 90, 250, 193, 215, 43, 161, and 132 feet.

It is unfair to pass a wholesale condemnation on gunpowder from tests however trustworthy, but made from samples, which there is strong reason to believe were among the very worst of their class. We know from the composition given by Mr. H. Hall, that the powder, used in the experiments made in Westphalia, was of very inferior quality. Gunpowder such as was there used would be represented by the worst of the samples given above, say 43 feet. Mr. Hall states that this powder contained 65 per cent. of saltpetre, 20 per cent. of sulphur, and 15 per cent. of charcoal. Powder of such a composition ought never to be used in any mine, and it is not just to condemn all powders from tests made with such inferior ones. It is presumed that the position taken up by Mr. Hall and others is that he is perfectly justified in testing the matter by the worst samples because they are at the present time in the market, and as the strength of the chain is the strength of its weakest link, so the safety of gunpowder must be determined by the worst of its class. But even judged by this low standard, gunpowder is shown by statistics to be safer than any other known explosive.

It is necessary to refer to the results of the mortar test and explain why there is such a difference in the propulsive powers of gunpowder.

* *Report . . . on the Tylorstown Colliery Explosion*, 1896, pages 17 and 18.

the other a solid, projected into the atmosphere of the mine in a highly heated condition, both of which are greedy for oxygen, and they immediately burn by combining with the oxygen of the air, and thus add, subsequently to the primary explosion, to the volume and intensity of the flame which is always and necessarily produced.

To how great an extent this intensity will be increased is evident from the fact that 1 pound of carbon in being oxidized to carbon monoxide develops 2,481 units of heat, and this carbon monoxide on being further oxidized to carbon dioxide develops another 5,599 units, or 8,080 units in all. The whole of this heat should be developed by the explosive within the bore-hole at the expense of its own magazine of oxygen, namely, the saltpetre. It is then capable of being of effective service, the heat is chiefly used up or spent in tearing the rock asunder, and its surplus heat is more or less dissipated and absorbed by contact with the cooling surfaces of the blasted material.

(*b*) We have to consider the effects of imperfect incorporation or milling. This is of the utmost importance, because it introduces into the problem the element of time. It should be remembered that there are three factors essential in a disruptive explosive, namely, the volume of gas, the temperature of the gas at the moment of the explosion, and the rapidity of the chemical change. Unless the milling be well done the action is slow. If the rock be partially disturbed, the remainder of the explosive is non-effective, and in the case of a blown-out shot part of the powder really burns outside the bore-hole. This slowness of action is further affected by the quality of the ingredients which need not be referred to in detail.

There are, therefore, in a low-grade powder two influences simultaneously at work—deficiency of saltpetre, resulting in the formation of a considerable volume of inflammable carbon monoxide, and, with imperfect incorporation, sluggish action. When powder of this character is fired without any stemming, or with but little stemming, a large volume of inflammable matter and actual burning powder is projected into the air, adding and unnecessarily contributing to the miners' risks.

From the foregoing remarks a high-grade gunpowder may be defined as one containing 75 per cent. of saltpetre, 15 per cent. of charcoal, and 10 per cent. of sulphur, all these ingredients being as pure as possible, and the charcoal made from either dogwood, willow, or alder. The ingredients should be so incorporated and finished that a 2 ounces charge gives a minimum projection to the ball of 140 to 160 feet.

A low-grade powder may be defined as one containing the ingredients

in any different proportions from that of high-grade powder and which, owing to bad incorporation and other imperfections in manufacture or in the quality of the ingredients, gives a result in the mortar under, say, 140 feet.

With a high-grade powder, a number of benefits could be obtained. For instance, the amount of charge could be reduced to the extent of not less than 30 per cent. From tests made in leaden cylinders, the proportion was ascertained to be as 7 to 10; that is to say, 7 parts of high-grade would perform the same work as 10 parts of low-grade powder. In addition, a greater length of stemming for a given depth of bore-hole would be obtained, and the powder being better placed for doing its work, there would be less smoke, and it is evident that less powder must mean less all-round risk. With high-grade powder there is much less risk of a blown-out shot. With an excessively slow-burning powder, of which a large quantity must be used, the pressure more readily acts on the lines of least resistance, and is therefore more likely to push out an insufficient stemming, but when the powder is quick and strong and better placed on account of the reduced charge, this result will not obtain to anything like the same extent. This opinion is proved in its most extreme form by the action of the detonated high explosives where the lines of least resistance are almost ignored by the explosive.

For a given amount of work, the cost of high-grade powder would be no more, although weight for weight it would be a little more expensive. The annexed photographs were taken in order to show how much greater is the amount of flame of low-grade powder (Fig. 1) as compared with high-grade powder (Fig. 2). The charges of powder in both cases were simply ignited in the open air with a red-hot poker, in the dark, the cap of the camera being removed just prior to the ignition. The greater volume of flame from low-grade powder is illustrated still further by experiments with the apparatus shown in Fig. 3, consisting of a four-legged stand supporting a wire gauze A, on which is scattered ¼ ounce of powder. The plate B can be moved up and down to any height, and ½ ounce of powder is placed on it and ignited by means of a red-hot iron. The lower position (51 inches below A) shows the distance at which poor or low-grade blasting-powder ignited the upper powder. The plate at 24 inches below A shows the distance to which it was raised before high-grade blasting and the best sporting powders ignited the upper powder.

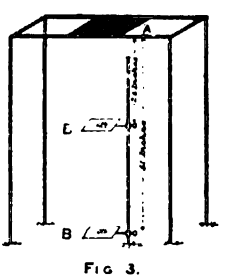


FIG 3.

In order to make this point still more conclusive, an arrangement was devised (Fig. 4) with a cannon, A, in order to imitate a blown-out shot. A number of sheets of paper were painted over with two coats of gunpowder paste, fastened to a light wooden frame, and then dried. This frame, B, was then placed at any desired distance from the mouth of the cannon. It must be remembered that gunpowder ignites at 620° Fahr., a temperature far below the igniting point of either coal-dust or fire-damp.

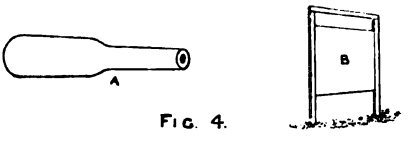


FIG. 4.

It was ascertained by experimenting made in this way with high-grade and low-grade powders without any stemming, that low-grade powders ignited the sheets at a far greater distance from the cannon than high-grade powders.

A large number of trials have been made with the same cannon with varying amounts of stemming, and with sheets of gunpowder paper. These experiments were made with 3 ounces charges of high-grade powder and the results may be generally summarized as follows:—(1) Without any stemming, the gunpowder paper continued to be ignited until the sheet was removed 15 feet from the muzzle of the cannon. (2) With 8 inches of stemming, no ignition could be obtained beyond 3 feet from the muzzle of the cannon. (3) With 10 inches of stemming, no ignition of the paper could be obtained. These experiments, therefore, clearly show that a blown-out shot with sufficient stemming will not ignite gunpowder, and much less therefore will it ignite coal-dust or fire-damp.

We arrive now at the important point of the whole question, namely, that the risks with gunpowder may be minimized, if not entirely obviated, by using (1) good, quick and strong or high-grade powder, producing little inflammable gas, (2) with sufficient stemming in order that the major part of the heat energy may be dissipated in mechanical and disruptive effects. The surplus heat, under these circumstances, exists only within the bore-hole and whilst the gases are under pressure. Immediately they escape into the mine-workings, expansion cools the gases below the temperature required to ignite any mixture of methane, coal-dust and air.

Sir Humphry Davy proved, in his researches on fire-damp, that mixtures of methane and air required to be heated to a temperature of about 1,200° Fahr. before ignition occurred, for in some cases as long as 10 seconds.

In a series of experiments carried out at the Lower Duffryn collieries in 1894, Mr. Jones had been successful in igniting coal-dust with slow-burning gunpowders under conditions which were foreign to coal-pit working, but when the same trials were made at the rock-face, and more or less stemming used with a view to causing blown-out shots, under conditions approximating to those in actual working, he failed to ignite the coal-dust, which was simply dispersed into the air.

From the remarks made by the Home Secretary to the recent deputation, at which the writer had the honour to be present, he is of opinion that it is most unlikely that any great modification will be obtained in the actual Coal-mines Order, and that the only direction in which pressure should now be brought to bear on the Home Office is, that in any tests to which gunpowder should be submitted in any experimental gallery, the conditions should approximate in every possible way to those of actual shot-firing in mines, especially as regards stemming; and if this be done, gunpowder of a uniform and strong quality cannot otherwise than justly find a place on the list of "permitted explosives."

Every miner knows that gunpowder is practically valueless unless well confined and stemmed. Therefore, it is submitted that it is grossly unfair to test gunpowder in any experimental gallery on the same lines as a detonated explosive with little stemming, and such experiments do not comply with the actual conditions obtaining in a mine.

The writer suggests that gunpowder and all other explosives should be subjected to the following tests before admission to the list of "permitted explosives" for use in coal-mines:—

(1) All explosives before being tested should be exposed for at least two weeks to an atmosphere something like that of an ordinary magazine.

(2) Gunpowder should be tested in a mortar, and with a 2 ounces charge should not be allowed on the permitted list unless it gives a distance of at least 140 to 160 feet.

(3) Gunpowder should be guaranteed to contain not less than 75 per cent. of saltpetre, and the ingredients should be perfectly free from all impurity.

(4) In testing gunpowder, the charges should be well stemmed.

(5) The amount of gunpowder charge should not be very different in weight from that of nitrate-of-ammonium explosives.

(6) The amount of the gunpowder charge shall be regulated to the nitro-glycerine explosives in the proportion of about 1 of gunpowder to 3 for the actual amount of nitro-glycerine present.

(7) In exploding gunpowder from a steel mortar in a testing gallery, a smooth-bore cannon should not be used. This would be unfair to

gunpowder, because with a smooth bore the stemming is more easily blown out. In actual mining work, the hole is necessarily rough, and the stemming gets a thorough grip of the sides, in fact, unless this be done the stemming with a smooth bore is really no stemming at all, and can only be compared to a well-fitted piston working in a smooth cylinder.

The writer hopes that he has been successful in showing the members that gunpowder, even taking it as at present made with its varying strengths and, in some respects, objectionable features, is not, after all, nearly so black as it has been painted. The gunpowder trade is desirous of doing all that can be done to mitigate the risks to human life and property, and will co-operate and assist the Home Secretary in any order which he may see fit to prescribe regulating the quality of the powder.

If this be done, the writer feels convinced that the risks to which the miner even at the best is exposed, will be considerably reduced; and it will be found that, taking into consideration the general fitness of gunpowder for the work, its safety in handling, its inimitable keeping qualities, its cheapness, and its adaptability under all conditions of climate and temperature, these and many other qualities will make gunpowder hard to beat.

APPENDIX I.—TABLE SHOWING THE TEMPERATURE DEVELOPED ON EXPLOSION BY VARIOUS EXPLOSIVES:—

	Degrees Cent.
Blasting-gelatine	3,220
Nitro-glycerine	3,170
Dynamite	2,940
Gun-cotton	2,650
Tonite	2,648
Gunpowder, high-grade	2,200
Roburite	2,100
Methane, fire-damp, ignites at	660

APPENDIX II.—TABLE SHOWING THE PERCENTAGE VOLUMES OF THE GASEOUS PRODUCTS FROM HIGH AND LOW-GRADE GUNPOWDERS:—

	High-grade.		Low-grade.	
Combustible gases—				
Carbon monoxide	10·94		33·75	
Hydrogen	2·52		5·22	
Hydrogen sulphide...	2·92		7·10	
Methane	0·29		2·75	
	——	16·67	——	48·82
Non-combustible gases—				
Carbon dioxide	49·61		32·15	
Nitrogen	33·62		19·03	
Other gases	0·10		0·00	
	——	83·33	——	51·18
		100·00		100·00

APPENDIX III.—TABLE SHOWING THE RELATIVE STRENGTHS OF BLASTING-POWDER AND NITRO-GLYCERINE EXPLOSIVES:—

	Relative Strength.
Blasting-powder, 62 per cent.	1·00
Dynamite, 75 per cent. of nitro-glycerine... ...	2·26
Blasting-gelatine	3·16

APPENDIX IV.—TABLE GIVING RELATIVE STRENGTHS OF LOW-GRADE GUNPOWDER, AND OF ROBURITE AND CARBONITE, CALCULATED FROM TESTS MADE IN ACTUAL MINING UNDER THE AUSPICES OF THE MINING INSTITUTE OF SCOTLAND:—*

Auchinraith colliery	Powder	1	...	Roburite	1·34
Lanemark colliery	,,	1	...	,,	2·20
Milnwood colliery	,,	1	...	Carbonite	1·56
Newton and Hallside collieries	,,	1	...	Roburite	1·32
,, ,, ,,	,,	1	...	,,	1·86
Mean	,,	1	...	Mean	1·65

The above tests were made with ordinary blasting-powder. High-grade powder is stronger as 10 to 7, and had it been used the figures would stand—Gunpowder, 1; and safety-explosives, 1·15.

Mr. J. T. FORGIE (Bothwell) said Mr. Hargreaves stated that during the 20 years from 1873 to 1892, there were 2,000 deaths resulting from the use of explosives in mines, only 664 of which had been proved as due to the use of gunpowder. Of course, the members presumed that Mr. Hargreaves was thoroughly satisfied that this was so, because they knew that an inspector of mines, who was a responsible person and a government official, in his annual report returned the number of deaths by gunpowder explosions at 2,000 in that number of years. He thought that Mr. Hargreaves should be very careful before he denied that statement of an inspector of mines. Mr. Donald M. D. Stuart had also made some statements to the same effect. From 1873 to 1892, the great bulk of the explosives used in mines had been gunpowder. He could not make a statement on the point, but he gave the opinion that a very small proportion would be other than gunpowder. The higher explosives would be used in sinking shafts, but in sinking shafts there was still no prohibition, so that they must confine themselves to the use of explosives in working mines, and between these dates there would be very little of these explosives used except gunpowder, although it had not been wholly used. While making these remarks, he did not for a moment wish to say

* *Trans. Fed. Inst.*, vol. xiii., page 246.

that gunpowder was not a proper explosive to use, because he thought that the experience of the use of gunpowder in the past did not warrant its abolition in the wholesale manner which H.M. inspectors of mines had insisted upon, and were seeking to enforce through the Home Secretary's order. The experiments of Mr. Hall proved a great deal, but he did not know that they proved conclusively that gunpowder was not a safe explosive. Further, they could not make a comparison between low-grade and high-grade gunpowder and a safe explosive without comparative tests. Such trials would be very interesting, because Mr. Hall based his recommendations on his experiments in the shaft in England by making comparative tests with ordinary gunpowder and high explosives. He threw coal-dust down the shaft, and exploded a cannon underground with gunpowder, roburite, carbonite, and other explosives, and he (Mr. Forgie) thought Mr. Hall's conclusion was that gunpowder certainly caused the greatest flame of any, and ignited coal-dust most easily. These experiments were made in the presence of anyone who liked to see them made, they were open to all, and it was a pity that the Gunpowder Trade Association at that time did not take steps to put themselves right, and have high-grade powder tested.

Mr. A. F. HARGREAVES said that Mr. Forgie had expressed himself very properly as regards the wisdom for extreme caution in pointing out inaccuracies in any official's figures. The matter had, however, been fully gone into by Mr. Stuart, who was an engineer and statistician of no mean order. The official records had been examined for the last 20 years, and the results, after careful revision and consideration, had been published by the Gunpowder Trade Association, and exact references were given for every statement. This examination undoubtedly showed that Mr. Hall had exaggerated (not to use a stronger word) the mortalities due to gunpowder in his crusade for its total abolition in coal-mines. As regards the weight of charges of gunpowder relatively to the other permitted explosives, all the testing so far had gone on a wrong assumption as to their relative disruptive strengths. Roburite, bellite, and other explosives of that class had for this purpose been treated as if they were really high explosives in the same sense as dynamite or blasting-gelatine, and the weights arranged accordingly. This comparison was not correct, for although they were detonated explosives, their real strength was not found in practice to be really very much more than gunpowder, and the charges of these explosives should not, therefore, be very much less than that of gunpowder. He believed that he was correct

in saying that roburite and bellite so far had been tested with weights of charges which in no case were ever used in actual practice. The minimum charge in actual work is 4 ounces, and to try cartridges of 1¼ ounces and place them on the permitted list because they fail to fire the gas and therefore assume them to be safer is scarcely fair.

Mr. F. J. Rowan (Glasgow) said that he had listened with great interest to Mr. Hargreaves' paper. He was very glad that he had directed attention to the use of high-grade gunpowder, because it seemed to him that many of the objections made to the use of gunpowder in the past ought to be removed in this way. He did not, however, agree with him in saying that this was not a manufacturers' question, and that it rested with the Home Secretary to say what sort or quality of gunpowder was to be used in tests. He thought, on the contrary, that it rested entirely with the manufacturers of gunpowder to produce an explosive that was safe, and to challenge the opinion of the Home Secretary upon it. It seemed to him to be a futile task to try and rehabilitate the old black-powder, as he was afraid that its day was gone. He had had an opinion for some time that gunpowder was being too summarily dismissed, and had wondered that the manufacturers of gunpowder had not long ago taken steps to put themselves in a better position with the mining world and the authorities. There were many ways in which gunpowder could be improved, and its bad qualities might be removed. The way in which the so-called safety explosives had been manufactured, he thought, conveyed some very valuable hints, if the manufacturers of gunpowder would only wake up and take advantage of them. For instance they had modified the action of the specially useful part of the explosive by means of chemicals which absorbed part of the heat of explosion and rendered them comparatively safe—why should not gunpowder be treated in the same way? Many years ago he had assisted in an experiment with a quick-burning powder, of which nitrate of potassium was the basis, but instead of submitting to the trouble and uncertainty of an admixture of the ingredients by milling, the carbon was supplied to the powder in the form of fine white sugar, and the powder was made in a very few minutes with a corresponding rapidity of chemical action. He thought that the makers of gunpowder ought also to find a substitute for sulphur, as it was a most abominable ingredient. He could not see much use for it except for the temperature produced by its combustion. It was a comparatively slow burning material, and he fancied that it added to the danger of blown-out shots. But a great part of the danger due to gunpowder undoubtedly arose from the combustible

products of its explosion which were shown in Appendix II. to Mr. Hargreaves' paper. It had been proved that, with coal-dust alone, the flame from a blown-out shot would not produce the bad effects that were certain where a small proportion of carbon monoxide was present with the dust. How the carbon monoxide was to be entirely removed was a question for experiment, and it was very satisfactory to see from the tables that by the use of high-grade powder the proportion could be reduced to one-third at once. He had no idea that there was so great a difference between the different powders as the table referred to represented. This table was certainly very interesting, and was of great value for educational purposes. In the mortar tests, they only got part of the truth, because it stood to reason that if there was, as Mr. Hargreaves had told them, nothing like the same proportion of difference between the various explosives that those figures represented, then in the low results a large proportion of the powder must have been shot out unburned. Therefore they wanted to know, before these tests could be considered of much practical value, how much was burned and how much was left unconsumed. In many of the laboratory experiments, and he thought in those in connexion with mining, the quantity of explosive left unconsumed was very often assumed. In those experiments where the cannon was used to fire the shots against paper covered with gunpowder, he did not think that the results were conclusive as showing the temperature produced, because the stemming itself would be shot out against the paper, and that would prevent to a certain extent its ignition from the flame that followed. However, if the quantity of high-grade powder which was required, as compared with the high explosives, was anything like as small as Mr. Hargreaves had said, it ought to be comparatively easy to overcome the other difficulties that were in the way of gunpowder. There was no question at all, from results that had been obtained, that the effect, especially on coal, produced by blasting with gunpowder was very much better from a miner's and coalmaster's point of view than where explosives with a high shattering power were used.

Mr. A. F. Hargreaves said that he was much obliged to Mr. Rowan for the very fair and reasonable criticism to which he had subjected his paper. He thought his preliminary remarks very reasonable and sensible, and he would not fail to bring the same before the Gunpowder Trade Association.

Mr. J. Gilchrist (Cumnock) said that Mr. Hargreaves might tell the members whether anything had yet been done in connexion with testing

of high-grade powder at the experimental station that had been fitted up by the Government at Woolwich. Mr. Hargreaves had made reference to Mr. Stuart's criticism of Mr. Hall's reports to the Home Secretary, and the President at the last meeting suggested that it might be desirable to discuss Mr. Hall's paper in connexion with the report on the Home Secretary's Explosives in Coal-mines Order, 1897. Mr. Hall had made so many different statements as to the number of deaths by the use of gunpowder for the years 1873-1892 that his statements could not be considered reliable. For instance, in his paper* the number of deaths through blasting with gunpowder in Scotland is stated to be 318; while Mr. Stuart stated that only 2 deaths took place in Scotland during these years, through explosion of fire-damp, by the use of gunpowder. It had just struck him that these were matters that the members of the Institute should be able to take up and discuss, for a great many of the members knew perfectly well what had been done during these years, and by comparing Mr. Hall's statements and Mr. Stuart's criticism they should be able to arrive at a true state of matters. He noticed that Mr. Hall gave 73 deaths as due to the explosion at Udston. Now, he thought that most of the members would remember distinctly that, at the investigation that took place and in the report by Mr. Dickinson, H.M. chief inspector of mines, it was not stated that the explosion was due to gunpowder, and he was sure that there were a good many of them who personally investigated the matter who would be able to state distinctly, whatever may have been the cause, that it was not due to the use of gunpowder. Some engineers said that it was due to a blown-out shot, but there was no evidence whatever of a shot being fired at the time of the explosion. Then Mr. Hall gave the result of the Blantyre explosion in 1877 as 207 deaths from gunpowder. They all knew how that pit was worked with open lamps, and it was not proved at the enquiry that the disaster was caused by the use of gunpowder. Probably some of the members would be glad to be informed where high-grade powder could be obtained and would be willing to try it.

Mr. HARGREAVES said that high-grade gunpowder could be easily got if members were willing to pay for it. He thought that it was scarcely fair that the permitted explosives should be put on the list without having undergone any official test. With regard to the statistics compiled by Mr. Stuart, he might say that he was particularly careful to charge against gunpowder all accidents where there was any doubt

* *Trans. Fed. Inst.*, vol. xi., pages 530 and 531.

as to whether it was due to gunpowder or any other cause. In any case, where there was any doubt, Mr. Stuart preferred that it should be credited to gunpowder so that his statistics might be on the safe side, and it was possible that some of the figures put down to gunpowder were not due to it.

The CHAIRMAN said that he had had extensive practical experience in regard to blasting, and he had some little sympathy with gunpowder as an explosive very suitable for mining operations. He hoped that Mr. Hargreaves and the Gunpowder Trade Association would be able to get high-grade powder placed on the Home Secretary's list of permitted explosives.

The discussion was adjourned.

The following paper, by Mr. J. A. Wauchope, on "The Gold-fields of the Hauraki District, New Zealand," was taken as read :—

THE GOLD-FIELDS OF THE HAURAKI DISTRICT, NEW ZEALAND.

By JOHN ANDREW WAUCHOPE.

In taking a general survey of New Zealand, before entering into specific details, a glance at the map of the Hauraki peninsula will show, not only its mountainous nature, but that it is easily accessible from all points, being situated on a most magnificent gulf, whose waters are never sufficiently ruffled to retard shipping operations. The fact of the majority of the mines being practically at the water's-edge is in itself sufficient to ensure it particular pre-eminence as regards the transport of machinery, stores, etc.

The gold-mining districts of the Hauraki peninsula are situated in the North Island of New Zealand, and consist of a long area of mountainous country, exceeding 100 miles from end to end. The peninsula runs in a north-westerly and south-easterly direction, Cape Colville being at the extreme northerly end, and the Waihi river at the southern extremity. To the east, there is a steep descent to the Pacific Ocean, and on the west, to within a few miles of Grahamstown—the Thames—it is bounded by the Waihou or Thames river, and from thence to Cape Colville, by the Hauraki gulf or Firth of Thames.

The auriferous belt varies in width from 12 to 20 miles, but gold has been discovered over the whole area.

The peninsula rises abruptly from the sea to the summit of the Colville range, which is the main watershed for the creeks to the east and west, these creeks providing ample motive power for mining machinery at all seasons of the year. The highest point of the auriferous range is Te Aroha, this mountain rising steeply to a height of 3,126 feet above the level of the sea.

Auckland, the principal city in the North Island, is situated about 37 miles to the west of Grahamstown, and is in daily steam communication with the various ports along the shores of the gulf.

Very little is yet known regarding the geology of the Hauraki peninsula. Owing to the thick undergrowth, combined with the rugged nature of the country and want of encouragement given by the New Zealand

government to geological research, little reliance can be placed on the information hitherto published by the Geological Survey Department. The whole region might be termed a region of chaos, having suffered, at intervals, great disturbance. It consists for the most part of a series of eruptive rocks ; and interstratified beds and local patches of slate occasionally crop up from below, showing the constitution of the platform upon which the volcanic materials were laid down. A comprehensive and systematic geological survey of the whole peninsula is required to satisfactorily work out the complications of structure presented.

Researches in the past go to show a general resemblance to the gold-bearing veins of California. The majority can scarcely be called veins, but rather ore-bodies, charged with gold by percolating waters: the metals occurring in these ore-bodies have been deposited by the chemical solution of their ingredients from the surrounding country-rock, which belongs to that type of igneous rock to which the name of andesite has been given, owing to its prevalence in the Andes. This propylite or decomposed andesite is known to the practical miner as the "kindly rock of the country."

The majority of the reefs are interbedded or segregated with the line of foliation running north-west and south-east, and are generally somewhat lenticular in character. They are most magnificent specimens of their type, and contain the usual constituents of gold, pyrites, galena, blende, ruby-silver, stibnite, manganese oxide, pearl-spar and calcite.

The theory has been advanced that reefs of this description are not so persistent in their downward continuity as true fissure veins. It has been alleged that they contain rich surface-deposits, but frequently pinch out with depth and cease with horizontal extension; but recent developments at Coromandel, Tapu Creek and other districts refute this theory so far as the Hauraki peninsula is concerned. Here, at least, they have been proved to exist at a depth of 1,000 feet below the surface. The only way wherein they differ from the true fissure vein is that they run parallel with instead of across the strata.

The occurrence of rich auriferous deposits in connexion with cross-veins or "flintys," at the point of contact with the parent veins, is particularly exemplified throughout the Hauraki peninsula. These injections invariably produce conditions favourable to the concentration of the richest deposits of gold.

Owing to the combination of adverse circumstances under which exploration, until recently, has been carried on in the Hauraki peninsula,

the prospector's operations have been confined to searching for alluvial gold and rich thin leaders that he could work himself, and whenever one of these was discovered it was worked until the richest portions were exhausted and then it was abandoned. These early seekers after hidden wealth only looked for gold in payable quantities, which meant nothing less than £5 per diem. Rock, with an assay value of 60s. per ton, was left because it would not pay to pack it to the battery. It may, therefore, be correctly inferred from what has taken place in respect to the intermittent and spasmodic attempts to develop the mines of the Hauraki peninsula that now properly directed operations are commenced they will be responsible for the production of increased dividends.

New country is being systematically opened up by the experienced prospector, making accessible its great mining as well as its forest wealth. Owing to the contiguity to salt-water of most of the mining districts at present under development, freights are low and labour cheap; while no climatic or topographical difficulties present themselves.

It is impossible to traverse any part of the Hauraki peninsula without marvelling at its magnificent growth of valuable timber. For mining, building, or trading purposes this timber has a value which every year will become more apparent. What with unlimited timber, beautiful and perpetual running streams of water for motive power, together with auriferous mountains rising to an altitude of many hundreds of feet, enabling the mines to be worked level-free by adits, this Hauraki peninsula is truly an ideal mining country.

Other industries also exist besides gold-mining which are capable of large and profitable extension, but remain undeveloped. Coal-seams are being worked in various places in a primitive manner, while the Taranaki district has been known to contain petroleum since 1866, when primitive boring operations were carried on with comparative success; again in 1890 the government sent an expert to report on the oil-bearing indications of the district, resulting in the compilation of geological and topographical reports and observations. In this report, the government expert stated that petroleum existed throughout a large area in the Taranaki district, and it was only a question of boring to the required depth to get at its source. The results of the analysis of the oil were very satisfactory, and it has been proved to be much more valuable than that obtained from the American oil-wells, showing from 50 to 60 per cent. of kerosene, whereas in America it is only about 35 per cent.

In relation to the mining industry, the past two years have been of the utmost importance to New Zealand. The introduction of the cyanide process, and the resuscitation of a great number of mines which had been practically closed down for many years owing to the want of suitable methods for the treatment of ores, combined with the great possibilities of the newly discovered auriferous areas throughout the peninsula, have given the mining industry of the colony an impetus amounting to nothing less than a revolution.

The history of New Zealand gold-mining, since attention was first drawn to it by Mr. Chas. King, a Californian digger, in 1852, when he discovered gold in the creek that crosses the main street of Coromandel, shows that all the exploration, up to the time of the introduction of the cyanide process, had for its object the finding of specimen rock, and thousands of tons of payable ore went over the dumps. It is true the miners were good alluvial diggers, but they were absolutely ignorant of quartz mining; that was not their business.

Waihi.—It is not the writer's intention to add anything that is new to what has already been written about the famous Waihi mine, but a little repetition at the present time may be of some interest. By way of showing what the cyanide-of-potassium process has done, attention may be drawn to the fact that the returns for the year 1890 were £20,930, and for 1896 they were £135,865, being an increase of £114,935. The old battery and berdan process was worked for nearly 12 years before the adoption of the cyanide-of-potassium process. The stamps had a capacity of 42 tons per diem. The ore contained an average assay value of £3 12s. to the ton; out of this, £3 per ton ran away in the Ohinemuri river, in the form of tailings, 12s. per ton representing the amount saved of the assay value, but the tailings were afterwards saved by the construction of pits. Recovery operations were commenced on the tailings in 1894; in a few months 20,000 tons were treated, bullion to the value of £25,000 was obtained, and a profit made of £15,000.

Assays taken from the tailings at various places in the bed of the Ohinemuri river show a value of £2 16s. per ton, and a company has been formed to work these deposits.

Although exceptional results are being obtained from the Waihi mine, very little enterprise has been displayed in exploiting the surrounding country. Within one mile of the Waihi mine, magnificent andesite country exists which, until quite recently, has been practically unexploited. That this stretch of country is auriferous has been proved

by the developments that have recently taken place in the vicinity of Walmsley Creek. To the west of this creek, the special claims, Napoleon, Goldfield, and Jess are located, from which very promising prospects have been obtained. It is alleged that the whole of this country assays from 10s. to £1 on the surface. The stone is of a bluish colour and heavily charged with mineral. To the south of these claims are the Waiuka, Martha Extended, Cecil Rhodes and Invincible. The Waihi Central, Carbine, Paul Jones and Esperanza are also located in the Walmsley Creek district. These locations are situated in a class of country that offers inducement for extensive exploration. In this district, where the Paul Jones claim occupied the premier position as regards developments, a monster lode, fully 50 feet wide, has been discovered. The Waihi Central has a masterly make of stone about 10 feet thick. The Coldstream United, Mount Waihi, Waihi Consolidated, Waihi South, Waihi West, Waihi Consols, Mount Waihi, Ohinemuri, Sir Julius, and numerous other claims located in the Waihi district are going in for systematic development. The Waihi Silverton ranks next to the famous Waihi. Last year 5,831 tons of quartz were crushed, yielding gold to the value of £10,177.

Waitekauri.—The whole of the auriferous section embraced in this area has recently been pegged out, and prospecting is being carried on with avidity. The western end of the barren looking range, which separates Waihi from Waitekauri, can be seen from the Junction claim in the form of a bold bluff of black rock to the north-east. In this neighbourhood are situated the Golden Lion, Heitman's Freehold, etc., claims. The country has not a very promising appearance; as the black rock overlying the andesite country will require to be penetrated before results are obtained.

The principal company operating at Waitekauri is the Waitekauri Gold-mining Company, who own the Golden Cross, Komata and other properties.

The Waitekauri United Gold-mining Company have recently acquired the Young New Zealand property, and are working the Point, Sheen, and Magazine reefs; tests recently made from these reefs show an assay value of £3 15s., £4, and £17 per ton respectively. The Waitekauri Extended Company are erecting a complete battery of the latest design, including the double discharge process, the stamps are 1,000 lbs. weight each, it is estimated that this 40 stamps battery should be capable of treating 100 tons of ore per diem, 70 men are employed and ore of payable quality is being won. The New Zealand Consolidated Mines Company,

Limited, took possession of the Waitekauri Union property last year. It consists of 700 acres, part lying to the north-east and part to the south-west of the Waitekauri and Golden Cross claims. Over 20 men are employed prospecting; on the central block, the low level has been laid off, which will necessitate about 1,000 feet of driving before the golden cross reef is intersected, and during the course of this work intermediary reefs will probably be intersected.

The Waitekauri Monarch, Kathleen, Zion, Waitekauri Reefs, Jubilee, Alpha, Rainbow, British Empire, Exchange, Portsea, Waitekauri No. 2, Grace Darling, Golden Spur, Sovereign, and numerous other claims constitute a group of properties, some of which known to be rich in resources are only partially explored and present many opportunities for exploration and preliminary working calculated to realize in the near future most satisfactory returns upon the initial expenditure.

The township of Waitekauri is located in the steep glen of the creek. The surrounding country consists of beautiful mountains, with their fantastic forms shooting up on every side, draped and festooned with a luxurious vegetation. The reefs are numerous and give great promise of permanency and richness. Some 6,125 tons of quartz were crushed in this district last year, valued at £22,041 3s. 10d.

Before passing on to Whangamata, mention may be made of Maratoto, North Waitekauri. Now that good roads are beginning to pierce the auriferous ranges of this district, experienced prospectors are exploring the heart of the mountains, and fresh discoveries are constantly being made. The group of claims comprising the Maratoto section are :—The Okotuku, the Great London and Liverpool, the Royal Mint, the Royal Mint Extended, Long Drive, Marguerite, Jason, Mexico, Maratoto, and others. These claims are composed of great parallel gold-bearing quartz-lodes, forming spurs, which rise to an altitude of 1,400 feet above creek-level, thus rendering the economic conditions highly favourable for their development and mining. These spurs rise precipitously from the bed of the Maratoto creek, a perpetual stream of water, and are clothed in a dense forest growth. The Maratoto property, with its colossal lode, impressed the writer very favourably. There are thousands of tons of ore thrown over the dump of an average assay value of £2 per ton. Thirty tons broken out of the main lode, and sent to Freiberg for treatment gave a return of £700. Altogether bullion to the extent of £17,000 has already been won from the property, and the writer feels confident that when the surrounding claims are worked systematically the existing reefs will be drawn upon to produce a golden harvest.

Whangamata.—Coming now to Whangamata, where it is said the largest and strongest quartz-lodes exist on the peninsula, little was known regarding the resources of this district until quite recently. During the last twelve months hundreds of claims have been pegged out in this section, but as the writer's knowledge of it is not very extensive, he does not care to venture an opinion upon any special property until he has made a thorough inspection of the whole section. The Whangamata Proprietary claim occupies the premier position. The Ptolemy claim comprises an area of 219 acres, and is traversed by a huge auriferous reef 23 feet wide. The Moa, Flemington, Luck-at-Last, Marco Polo, Prince Charlie, Rothschild, Sybil, My Sweetheart, and numerous other claims are embraced in this section. It is predicted by reliable authorities that Whangamata will soon add a respectable sum to the wealth of the colony and take a permanent place among her mining centres.

Karangahake.—The mines in this section are situated on the slopes of the Taukin range, at the confluence of the Waitawheta and Ohinemuri rivers. The hills in this locality, with their seared sides, rise bold and rugged to an altitude of about 1,000 feet above creek-level, terminating in small areas of flat table-land, with deep ravines emptying into the rivers to the north and south. The country-rock embraced in this section is generally propylite or decomposed andesite. On the northern slope of the range, this andesite or propylite is principally of a greyish-blue colour, usually impregnated with veins and seams of iron pyrites. The principal lodes traversing this section all have about the same angle of bearing, *i.e.*, 10 to 20 degrees east of north. The reefs are heavily charged with pyrites and oxide of iron.

The Crown and Woodstock mines are being worked by dry crushing with stamps and cyanidation. Last year, 8,075 tons of quartz were crushed, being an increase of 2,962 tons over the amount crushed in the preceding year, valued at £30,557 17s. 3d. Of this, the Crown mine crushed 7,295 tons, valued at £26,951 17s. 3d.; the Woodstock coming next with 496 tons, valued at £1,461; and the Talisman contributing the balance of 285 tons, valued at £1,461. The Crown mine was the means of introducing the cyanide-of-potassium process into the district. The names of the other mines composing the Karangahake group are:—The Imperial, Deep-head, Hercules, Golden Giant, Crescent, Excelsior, Karangahake, Mariner, Wealth of Nations, South British, Golden Fleece, Maritana, Crown Reefs, Reefton, Asteroid, Eileen, Tenilba, etc.

The main-road from Thames to Waihi passes through Karangahake,

along the northern bank of the Ohinemuri river. This river is navigable as far as the township of Paeroa, which lies about five miles to the north of Karangahake, and occupies the position of terminus for the Northern Shipping Company's steamers. Paeroa is the distributing centre for the Ohinemuri district.

Te Aroha.—Judging from the amount of development work done in this section, and the amount of bullion obtained from the quantity of ore treated, and the loss made by the old battery process, it is quite evident that with modern appliances and a suitable process for the treatment of the ores, this section of the Hauraki peninsula will enter upon a period of activity and prosperity such as it has never before experienced. Among the mines from which returns may be expected in the near future are :—The Lord Nelson, Premier, Premier Extended, Admiral Fairfax, Taranaki, All Nations, Loyalty United, Merchant of Venice, Waiorongomai, and others.

There are several other sections situated in the southern end of the peninsula, which have recently been proved to be auriferous, but they have not yet entered upon the initial stage of development.

Puriri.—In passing from the Upper Thames sections to that of the Lower Thames, reference may be made to the Puriri district, where some very promising properties are located, and where extensive development work is being conducted. There are a number of claims pegged out here, but the only one that the writer visited is the Hit-or-Miss. The reefs in this mine are numerous and rich. One ton of ore sent to the School of Mines for treatment was subjected to hot-pan amalgamation, which recovered 23 ozs. 13 dwts. of melted gold, and the total value of the ore was £61 15s.

Lower Thames.—Some of the early discoveries in this section read like a romance. Within an area of 640 acres over £6,000,000 of gold have been won from what might be termed surface-workings. It may be justly considered the richest field ever known in the world. The history of this field may be said to have commenced with the discovery of the famous Shotover claim, and the immense quantities of gold won from this location gave it a world-wide reputation. This property was taken up on the information supplied by the Maories to Mr. Hunt, who, in company with three others, pegged out the outcrop of a reef which was literally impregnated with gold. To the west of the outcrop, in the

bed of the Kuranui creek, thousands of golden nuggets were discovered which had been liberated from the parent vein. These four men divided £160,000 between them out of the metal won from the reef before they sold out, and after they disposed of it, nearly £16,000 was paid away to the new company in dividends.

The discovery of this fabulously rich shoot of gold created a sensation all over the world, causing an invasion of between 15,000 and 16,000 adventurous diggers of all nationalities, forsaking the rich alluvial fields of Bendigo, Ballarat, Castlemain, Campbell's Creek, Clunes, Creswick, and other Australian gold-fields, while many went from California and other parts of the world. It is an old story now, how this daring and ambitious army, each a stranger among a strange crowd of adventurers, crossed the Pacific Ocean, at the time of hostilities with the Maoris, which prevented for many years any progress in the mining operations, and set up their tents on the shores of the Hauraki Gulf—how these courageous, trusty and tried pioneers, conquering all physical difficulties, invaded the mountain fastnesses of New Zealand and wrestled with Dame Nature for her hidden treasures.

The Shotover discovery was followed by that of the Long Drive. This famous mine in a short period yielded over £100,000 worth of gold.

The next sensational discovery laid bare on the surface was a showing of golden stone, completely overshadowing all previous discoveries; this was called the Manakau, and yielded enormous quantities of the precious metal. The track of this phenomenally rich make of stone was next traced into what is now known as the Golden Crown claim. After clearing thousands of pounds each as the reward of their labours, the original prospectors of this property transferred it to a company, and the sum of £141,904 was afterwards divided among the lucky shareholders.

This remarkable ore-body was next exposed in the historical Caledonian mine, a veritable El Dorado, fit material for a romance by Mr. Rider Haggard. In two weeks this claim yielded over 25,000 ounces of gold. The incidents related by men who worked in this mine would indeed form the nucleus of a thrilling romance; of shots being fired and bringing down hundredweights of reef matter in which there was more gold than quartz; of bars of solid gold sandwiched between layers of rock showing in the face of the drive; of the 10 tons of the noble metal won in as many months, enabling the fortunate shareholders to divide £553,440 in dividends within twelve months. The area of this famous mine was only 2½ acres.

In addition to the mines already enumerated, various other properties in this section were responsible for the production of phenomenal yields of gold, amongst which special reference might be made to the Alburnia, Old Whau, Cambria, Moanataiari, Kuranui, and Waiotahi. Last year at the Waiotahi mine 2,006 tons of quartz were crushed, which yielded 2,430 ozs. 16 dwts. of gold, valued at £6,660 5s. 1d.

Each of the above mentioned claims has been profitable. One of them yielded over 10,000 ounces of gold in one week. These results were obtained with the old-fashioned battery and amalgamation process, without accessories, and of course represents only what was saved. Independent of the large percentage of their values which went to waste, the quantity of gold won, which was never recorded, must have been something enormous. Some idea of its magnitude will be gained when it is stated that the yield represents an average of over £7,575 per acre, and, judging from the systematic conduct of operations which were being carried on, the writer has not the slightest hesitation in saying that it has every indication of further great mineral richness in the immediate future.

The whole history of New Zealand mining goes to prove that whenever a rich shoot of gold ran out or a fault was encountered, or when water was struck in a winze, the workings were abandoned, constituting a chapter of history somewhat foreign to the history of mining development.

At the time of the writer's departure very few of the mines in this historical locality had been worked to a greater depth than from between 400 and 500 feet. The May Queen, the Prince Imperial, and the Piako had barely exceeded 500 feet.

The New Alburnia, from which exceedingly large returns have been obtained in the past, has only reached a depth of about 400 feet, but deep prospecting has been inaugurated on an extensive, systematic, and workmanlike manner. Although the ore at present being milled at this mine is of low grade, there is a probability of its improving in value at any moment. The writer had the pleasure of breaking out a quantity of rich specimen stone at a depth of 370 feet. The ore is transported from the mine to the battery, a distance of over one mile, by an aerial tramway. The cost of treatment is 3s. 6d. per ton.

The Queen of Beauty section of the Thames-Hauraki mine was on rich gold at a depth of 747 feet, but owing to an influx of water and the breakdown of the pumping machinery, the mine was closed down before any systematic mining had been done.

The largest gold producers in this group are :—The Moanataiari, May Queen, Hazelbank, Victoria, and Waiotahi. In addition to the above mines the following have produced gold in varying quantities during the past year :—The New Alburnia, Adelaide, Broken Hills, Cambria, Cardigan, Darwin, Devon Castle, Freedom, Karaka Queen, Gloucester, May Queen Extended, Monowai, Napier, Nonpareil, Occidental, Orlando, Scandinavian, and Manchester. The Tararu Creek mine crushed 2,343 tons of rock last year, which yielded 1,930 ounces of gold, valued at £3,398 13s. 11d. Owing to an exceptionally dry season, the water available for motive power has only been sufficient to run 10 heads of stamps for some considerable time, consequently the returns from this mine are not nearly so large as they would have been under more favourable conditions. Large quantities of payable ore are in sight, and the prospects are highly encouraging. The main reef carries strong ribs of rhodonite quartz on the footwall side, while veins of galena, showing free gold, are in evidence in the body of the reef ; fully 16 feet from the footwall has been cut into without even an approximate idea being formed of the dimensions of this splendid ore-body, there being no sign of the hanging wall. The whole width of the lode is saved for treatment.

The spurs upon which this group of claims are located rise precipitously to an altitude of over 1,200 feet above sea-level, leaving about 800 feet of backs in the mines enumerated intact before beach-level is reached.

Now that deep prospecting has commenced in this section under the direction of trained engineers, the writer is confident that it will enter upon a long era of prosperity. For many years these mines have been closed down owing to ignorance. Capital has been shy in embarking into New Zealand mining, because there were people foolish and ignorant enough to assert that the reefs pinched out with depth and ceased with horizontal extension. As an exemplification of the absurdity of this theory, so far as New Zealand is concerned, we have only to look at the Hauraki Mine, Coromandel, and the Queen of Beauty, Thames, in which gold has been proved to exist at a depth of 1,000 and 747 feet respectively. The writer has always found the miners' pick a truer index than the average mining expert. "You men learn to scrat afore you peck," is a good old Shropshire adage, honoured though by the mining expert more often in the breach than in the observance.

The cardinal symptom of the malady in New Zealand mining has been scepticism instead of faith in the resources of the country. The

influences of this scepticism have worked shameful perversion of judgment; but the old order of things is passing rapidly away and the mining industry is drifting daily towards new issues and combinations. The scientific accuracy of some of the mining machinery at present in course of construction is a revelation, and scientific methods are being substituted instead of the old methods which were in vogue twelve months ago.

Puru.—Owing to the developments which have taken place in the Puru Consolidated Company's property, this district is attracting a considerable amount of attention. The area of this property is 500 acres. At the time of the writer's visit to this mine, the main lode averaged from 3 to 5 feet in width, and carried gold for a length of 150 feet. Between 200 and 300 tons of ore were at grass ready for crushing; colours of gold were showing all through it. This magnificent ore-body has been laid bare at such well chosen spots as to exhibit its size and continuity. The difficulties in the past in respect to the facilities for obtaining access to this auriferous district are gradually being overcome, and fresh discoveries are being made every day, and innumerable claims pegged out, some of them of surprising richness.

Tapu and Te Mata Creek.—Tens of thousands of pounds worth of gold have been won from this district in the early history of the field. The main lode of this section, which is one of the strongest the writer has seen in New Zealand, outcrops in the two properties known locally as the Bennett and Campbell freeholds, which embrace a combined area of 300 acres. This lode is highly auriferous, and measures 12 feet from wall to wall; its angle of bearing is north 25 degrees west, and underlies to the east. With it is allied the Royal Standard reef, which is about 4 feet in width; its course is north-north-east. These two lodes run together on the boundary of the two properties. These two properties are a perfect network of reefs, all more or less auriferous. They are found in bands or belts of propylite or decomposed andesite, and separated from each other by bands of andesite-lava. They are chiefly of the interbedded class, and derive their metallic ingredients from the solution of the rock in their immediate vicinity.

This section has never been systematically worked. Hitherto the work has been practically surface-work, a mere scratching, yet thousands and tens of thousands of ounces of gold have been scraped out of the ravines and creeks. Gullies have been worked and abandoned without

common intelligence being exercised to test the quartz-veins from which the gold was shed. Whenever the specimen portions of the reef already enumerated were exhausted they were abandoned. The writer's fire-assays from the quartz thrown over the dumps on the two properties referred to ran from 16s. to £164 per ton. These areas originally comprised within their boundaries the Lord Nelson, Victory, Prince of Wales, Diggers' Rest, Royal Standard, Tapu Creek Gold Mining Company, and various other claims. The yield of gold was from 2 to 15 ounces to the ton, and worth from £3 3s. 6d. to £4 2s. 6d. per ounce, being the highest value obtained in the whole of the peninsula.

The gold in nearly all of the other sections is alloyed with silver to the extent of 30 to 40 per cent., and is worth only from 48s. to 56s. per ounce. In the Thames section the average fineness is about 680. On one occasion, the Royal Standard Gold-mining Company declared a dividend of £10 per share, being the result of only three weeks' working, while from the Lord Nelson no less than 18 ounces of gold were obtained from three tin-dishes of stuff. The manager of the Tapu Creek Gold-mining Company informed the writer that with the crude appliances at hand £120,000 was won during his four years' term of office. He once took 1,417 ounces of gold out of nine bags of ore, a little over one ton.

The quartz-lodes composing the above claims form spurs which rise to an altitude of 1,200 feet. These lodes have never been tested below 150 feet from the summit of the range, so practically the whole area is intact.

The reason why this rich area has remained idle so long is because the Tapu homestead selections were withdrawn from the gold-fields area by royal proclamation, and compensation was granted by the government to the proprietors for trespass and the various mineral leases were cancelled. Having no knowledge of mining, and viewing all those who had with suspicion, the owners of these properties preferred to run a few sheep and cattle on the country to searching for gold.

Some 20 years ago, sluicing on a primitive scale was carried on in the Campbell freehold. They had a very small water-race, little or no machinery, and only most crude appliances; notwithstanding this, the manager who was in charge informed the writer that the results were highly satisfactory. About 200 feet below the summit of the range, the face of a hill is exposed for about 200 or 300 feet, where these operations were carried on.

If a water-race were constructed from the head-waters of the Te Mata creek, a distance of about 10 miles, and sluicing conducted on an

extensive scale, the writer is confident that highly payable results would be obtained, as he has proved this hill to be auriferous by assay tests.

Rich gold can be panned off by the ordinary tin-dish in almost any part of the Te Mata and Tapu streams. Gold is also obtained at the mouths of these creeks along the Hauraki gulf. With each successive flood down these streams, the hills have been washed away, and new channels formed through auriferous country, washing the metal out of the reefs and distributing it along the stream-beds and along the beach.

The Little Jessie claim embraces an area of 27 acres. It is bounded on the north by the Campbell freehold, and situated at the head of what is known as No. 3 Gully, which runs into Tapu creek. This gully offers a spectacle of picturesque beauty never to be forgotten. The writer has never seen any scenery in variety of form and colouring, beauty and greatness combined, to equal that of this locality. Nobody could describe the view from the head of this ravine, with its forests of noble tree-ferns and semi-tropical beauty ; for of all the forms of semi-tropical vegetation the tree-fern is certainly the most striking and beautiful. The view of their feathery crowns, in varied position and of varied shades of green, is indescribably lovely. To the south, across the Tapu creek, the mountains rise precipitously, covered with vegetation and torn by deep shadowy ravines. This lofty line of peaks, lifted from the bottom of the sea by some ancient and stupendous telluric spasm, contains treasures which Dame Nature holds out to men of endurance and pluck.

The Little Jessie claim was abandoned in the early days, after the richest portions of the vein were exhausted. The work done at that time was all surface-work, and confined to a leader 18 inches thick, which averaged from 7 dwts. to 10 ounces to the ton. Operations have recently been recommenced, a low level has been driven, and this leader cut at a depth, at which point it has developed into a fine masterly make of stone, 6 feet in width, showing strong colours of gold from wall to wall, and carrying a considerable amount of pyrites disseminated through the ore. The country rock penetrated by this level is an argillaceous schist or slate. There are other reefs, all more or less auriferous ; and the Royal Standard No. 1 reef—12 feet thick—must pass through on its southern trend.

The Golden Point is situated on the northern bank of the Tapu creek. A shaft has been sunk to a depth of 220 feet below sea-level and a reef intersected at that depth by cross-cutting to the west. At the time of the writer's last visit this reef was about 2 feet in width, and showed coarse gold. Judging from the disturbed state of the country at this

point, it will be necessary to carry this shaft down to a much greater depth before actual mining is commenced. On this ground there is a complete winding and pumping plant.

The Sheridan claim is situated on the southern side of Tapu Creek, which separates it from the Golden Point claim. It is divided into three sections, the combined area being 100 acres, carrying three distinct systems of reefs. A considerable amount of work has been done, proving that some of these lodes extend to a considerable depth below the surface, while the length of the ore-shoots indicate permanent gold as they go down in depth. The Sheridan reef averages about 2 feet in width, its angle of bearing being 20 degrees east of north, with an underlie to the east of about 40 degrees. From where the Sheridan reef was first intersected, a drive has been driven to a distance of about 160 feet, the lode here suffering a displacement; the fault and its course is clearly marked by the alteration it has made on the surface. The lode has never been searched for from where it faulted, and remains intact. The section opened up by this drive has been stoped out and 113 tons of ore were milled, which yielded 563 ozs. 10 dwts. of melted gold. From No. 3 level upon this reef, a winze was sunk to a depth of about 50 feet, from which 330 tons yielded 300 ounces of melted gold; but just at the time that high-grade ore was coming to hand operations had to be suspended on account of an influx of water. The country-rock has undergone extensive alterations by the leaching process of chemical solution. The ore-body consists of quartz, pyrites, galena, calcite, etc., showing that the solutions were highly charged with carbonic acid, the calcium being derived from the felspars in the rock. With the object of more extensively exploiting this mine, a main adit-level is now being driven from the creek, and all the ore-bodies traversing the area will be intersected at a depth giving from 200 to 300 feet of backs. With a view to determining the dimensions and value of the reef at the bottom of the winze, it was recently drained, and a fine, strong masterly body of ore presented itself at the lowest point reached. A trial parcel of 100 tons was broken out and crushed at the battery, and yielded over 1 ounce to the ton. According to the writer's assays from the tailings and slimes, about 50 per cent. of the assay value of the ore was going to waste. On the south side of this winze, the lode matter is fully 10 feet in width, and on the footwall, for a thickness of 2 feet, bunchy gold was very conspicuous through the ore. On the north side of the winze, the lode showed a thickness of 6 feet of high-class ore, divided into numerous quartz-veins, with intervening bands of country-rock, the whole body

presenting a network of highly auriferous ore. The veins of quartz were full of vughs, with bunches of calcite appearing here and there. Intermixed with the calcite, bunchy gold of a curious character was very conspicuous, and at any time a heavy deposit of gold may be met with. Until recently, all the ore was carted down to the Thames, a distance of 13 miles, where it was treated, the carting alone costing £3 per ton. Some 200 tons treated from the Sheridan and Bullion reefs in October last yielded 198 ozs. 17 dwts. of gold, valued at £619 11s. 9d. This ore was treated by the ordinary battery and amalgamation process, fully 50 per cent. of the ore-value running away in the tailings.

The Comet, Mata Reef, Hawke Freehold, Sheridan No. 2, Club, Golden Horn, and numerous other claims constitute the Tapu group, while a few miles up the creek is the Mahara Royal claim. The writer has never seen this property, but he is informed on reliable authority that it gives promise of great mineral richness.

Both the Tapu and Te Mata creeks are perpetual running streams of water which can be utilized for motive power.

There is a government wharf at the entrance to Tapu creek, where vessels can load and discharge cargo, thus making the transport of machinery easy.

Coromandel.—The premier gold-producing company at present operating in this section of the peninsula is the Hauraki Gold-mining Company. This was one of the first corporations to turn its attention to gold-mining in the North Island, and it well deserves the success now attending its efforts. Since the end of May, 1896, gold to the value of £44,799 has been won at a cost for treatment of £12,110. The average yield of gold per month is £6,427, the expenditure is £1,725, and the average profit amounts to £13 1s. per ton. The total amount of ore crushed last year was 4,421 tons, yielding 29,077 ounces, valued at £87,391 18s. 2d.

The other principal gold-producers belonging to the Coromandel group are the Kapanga, Scotty's Hauraki, Success, Hauraki North, Royal Oak, Tokatea of Hauraki, Hauraki Associated, Welcome Find and the Kauri Gold Estates. The latter contains an area of 37,000 acres, all more or less auriferous, and a trial parcel of 2 tons yielded 225 ounces of gold, valued at £675.

From its method of working and the satisfactory results obtained by deep sinking, the Kapanga mine is certainly the most typical of the Coromandel group. The attempts that have been made to work this

mine have hitherto been of a spasmodic and intermittent nature, but the present company have inaugurated extensive and systematic developments with most gratifying results. The main shaft of this mine has reached a depth of over 1,000 feet, and can lay claim to being the deepest shaft in the North Island. This property has an area of about 100 acres, and is located halfway down the western slope of the ranges to the north-east of the township of Coromandel. The bulk of the operations have been conducted on the Kapanga and Scotty reefs. The former is a compact make of stone, while the latter is of a soft and puggy formation; both of these reefs vary a great deal in their gold-bearing proclivities, as well as in their conformation and regularity. The marvellously rich ore which is obtained in these reefs occurs in bands or shoots, which are divided by apparently barren places, but it is alleged that it will pay to crush the whole of the lode-matter. There is a popular impression amongst mining men to the effect that the rock which divides the two reefs is a mullock horse, and that they will unite at a depth forming one great ore-body. Nearly £50,000 worth of gold have been won from this mine, which has, to all practical purposes, just commenced operations. The Scotty reef was struck in the Kapanga main shaft at a depth of 600 feet, thus proving the above reef for that distance. From the 620 feet level to the 745 feet level, some 14 or 15 rich leaders were cut. A reef 7 feet in width was discovered in a shaft sunk to a depth of 800 feet. In a cross-cut driven from the bottom of this shaft, in a westerly direction, at a distance of 50 feet a 5 feet reef was exposed, and at 200 feet another reef was brought to light, measuring fully 12 feet in width, while at a further distance a third reef was intersected. The country to the east of the shaft has not yet been proved, but large bodies of payable rock are known to exist between the surface and the low levels.

The belt of country embraced in what is known as the Tokatea range has been responsible for the production of some marvellously rich stone, both on the surface and at a depth. When rich ore has been proved to exist at a depth of 1,000 feet, a prosperous future may safely be prophesied for the locality. Last year, 572 ozs. 8 dwts. of gold was won in the course of exploitation from this mine, valued at £1,628 10s. 2d. Large quantities of the stone discovered in this section have crushed from 6 to 7 ounces of gold to the pound of rock.

The Scotty's Hauraki claim is situated due north of the Kapanga. The reef system traversing this property has the same angle of bearing as that of the Kapanga, which runs nearly north and south. This mine

has been responsible for some of the richest surface-deposits ever found, and 70 tons crushed recently yielded 66 ozs. 14 dwts. of gold, valued at £199 7s. 9d.

In the Success mine, veins have been discovered and worked which contained more gold than rock; and 100 tons crushed last year yielded 108 ounces of gold, valued at £324.

The new crushing plant for the Hauraki North mine has just been completed and is now working. Some exceedingly rich specimen stone has recently been won from the reef at No. 2 level. Gold is now showing in the face of all the workings, *i.e.*, in the easterly low level, in the winze, on the main reef from No. 1 level, and in the stopes off the rise above No. 1 level. The reef at the eastern side is over 2 feet in width, carrying good payable ore. In the winze referred to, connecting No. 1 level with No. 2 level, there is a reef of payable ore over 3 feet thick. The prospects of this mine are exceedingly promising, and 82 tons of rock crushed last year yielded 215 ozs. 3 dwts. of gold, valued at £646 5s.

In considering the returns from these mines, it must be remembered that they are only trial parcels, and that operations are confined merely to exploitation work, mining not yet having commenced in any of the mines enumerated, with the exception of the Hauraki.

Kennedy Bay.—It is estimated that over 200 men are engaged in this district, either in mining or prospecting. It is one of the most extensive and promising of the recently discovered gold-fields, and includes that immense area of land which embraces the western slopes of the Tokatea range. Some two years ago the first gold-bearing lode was discovered in this section by two residents of Kennedy Bay while prospecting up the Mataiterangi creek. This reef is known as the Bay View reef, and other good reefs have since been located.

From the bed of the Waikoromiko creek rich quartz-specimens and free reef-gold have been won in large quantities. These specimens varied in size and value from £20 to £50, the majority of them showing no sign of travel. Consequently, it is safe to assert that a little systematic search will reveal the veins from whence they were shed. In fact, some of them have already been located, and proved to carry payable gold. As yet, however, the industry is young, and only in the prospecting stage; but what it may be in a country of such mineral wealth it is difficult to foresee.

In the Whareroa, the Mataiterangi and various other creeks which drain the country west of the bay, gold has been found in varying quantities. It also exists to the south towards Matamataharakeke.

Kennedy Bay is only about 7 hours' steaming from Auckland. It is perfectly safe from a shipping point of view, being well sheltered, with an unlimited supply of wood and water on its shores. On the southern side of the river a large area of good flat agricultural country exists, which runs up the Waikoromiko. The Maoris have had some of these flats surveyed and laid out for a township. Sections have also been surveyed and a township laid out on the north side. Large quantities of timber have been shipped in the past from this bay, and old tramways are to be seen traversing the bush in all directions. Millions of feet of the famous kauri pine still exist on the ranges.

A new battery is at present being erected by the owners of the Pride of Tokatea, with which it is intended to crush for other mines as well. The battery site is most convenient, at the confluence of two splendid streams of water.

Although hundreds of claims are pegged off in this promising section, there are only a few that have gone in for systematic development, consequently it would be rash to predict its future.

Similar remarks apply to the Cabbage Bay, Port Charles, and Mercury Bay districts.

Kuaotunu.—This section of the peninsula is well known for its large and permanent auriferous lodes. A large area of this district is practically virgin country. Like most large ore-bodies, the Kuaotunu lodes carry comparatively low-grade rock, which holds the gold in a very finely divided state, necessitating special treatment. The parent reef has been traced for over two miles in a northerly direction seaward from the Try Fluke and Kapai-Vermont mines, and it has been located some considerable distance to the south, thus proving its permanency and continuity. It varies from 3 to 6 feet in width, with a dip of about 65 degrees, and carries gold in varying quantities. Although this ore-body is classed as low grade, the writer ventures to say that the general average will be over 1 ounce to the ton.

The recent improvements in the Try Fluke mines machinery enables them to pay all working expenses on rock yielding 15s. of gold per ton. This mine has chiefly confined its operations to surface-work, the lowest level only giving them 140 feet of backs. Still, there is a huge body of stone in sight, and it may safely be premised that this masterly make of stone will live to great depths, and be responsible for the production of good payable ore for many years. The Try Fluke and the Kapai-Vermont mines are to be congratulated upon the success

attending their operations, owing to the merits of their treatment of the ore. The Try Fluke mine has a cyanide plant at work, and last year 1,952 tons of quartz were crushed, yielding 904 ozs. 15 dwts. of gold, valued at £2,058 5s. 5d. The area covers 106 acres.

The area covered by the Kapai-Vermont mine is comparatively small, but it embraces several masterly lodes. The ore is treated by dry crushing in an Otis mill and direct cyanidation; and this system is working with most satisfactory results. Before the quartz is crushed it is dried in two kilns, each 12 feet in diameter at the top, with a depth of 27 feet, and a combined holding capacity of from 140 to 160 tons of ore. Over 90 per cent. of the assay value of the ore is extracted. The capacity of the mill is about 1 ton per hour. Last year, 2,961 tons of ore were crushed for 3,403 ounces of gold, valued at £8,403 4s.

The Great Mercury mine has been working for some considerable time, and, although the average does not reach that of either the Try Fluke or Kapai-Vermont mine, the average value of ore obtained is £2 per ton, and the returns for last year amounted to £3,626 6s. 2d.

A geological survey of this district is at present being conducted by Mr. A. McKay, one of the best authorities on New Zealand mining. It is rumoured that, as a result of this survey, a most valuable discovery has been made of an extensive thermal character, favourable for the carrying of gold. It is said that these deposits cover so immense an area that it is difficult to grasp their extent. The writer understands that this area is actually a sinter deposit, in origin almost identical with the famous Mount Morgan, of Queensland. If these deposits prove payable, Kuaotunu will immediately leap to the premier position of New Zealand gold-producers.

The Irene, Great Barrier, Fortuna, Golden Link, Ainsworth, Golden Anchor, Kuaotunu, Maori Dream, Abercorn, Invicta and other claims are situated in this section. From all of these claims, when opened up and the veins exploited, according to the local laws of ore-deposition therein, the writer is confident that large yields will be made for years to come.

The Great Barrier Island, which is geologically part of the Hauraki ridge, has also been found to be highly auriferous; several claims have been pegged off, and satisfactory trial-crushings obtained, but sufficient work has not been done to even form an approximate estimate of its value.

The following is a synopsis of the value of the gold won during 1895 from the sections enumerated:—

	£	s.	d.
Upper Thames	198,925	4	7
Lower Thames	31,663	6	1
Coromandel	87,391	18	2
Kuaotunu	14,685	17	4
Total	£332,666	6	2

It is estimated that the yield in round numbers for the past year will reach £500,000. It is absolutely impossible to tabulate the numbers of trial crushings, private tailings, etc. Besides the sections already enumerated, a number of promising claims have been pegged off in other localities, and are now being worked. With present facilities for prospecting, much larger returns are expected in the near future, for the era of scientific mining has only commenced in New Zealand.

There are about 320 locally registered companies operating in the North Island, and 40 English companies.

Beach-washings.—Although the writer has only dealt with the quartz-reefs of the Hauraki peninsula, there are other forms of mining which he is sure would pay to work, *i.e.*, beach-washings, placer-mining and dredging. For many years rich deposits of black sand have been known to exist on the beaches of the Hauraki gulf, and considerable prospecting has been done from time to time, but the results by the ordinary methods of panning have not been sufficient to induce working these sands on a large scale: although rich in gold they are exceedingly rebellious. But, in this age of science, this difficulty will be soon overcome, especially when showing such good assay values. A considerable amount of money and time has been spent in experimenting and testing the black iron sand on the west coast, but met with little success, as the action of the iron on the cyanide of potassium destroyed its effect on the gold.

On several portions of the coast there is special dredging-ground in the shape of auriferous sea-beaches and in low flats, which fringe the sea in places, and are locally known as *pakihis*, all of which are known to be rich in gold. Along the beaches, there are millions upon millions of tons of black iron sand both in the North and South Islands, in a large proportion of which gold is visible to the naked eye. No doubt the gold in these river-heads and creeks and on the beaches has been separated from the parent veins through the action of the atmosphere and water, and brought down by floods, swept into the sea, and washed back again by the waves. Notwithstanding that these rich deposits are known to exist, beach-dredging has been pronounced a failure, and what is now required is a successful method of saving gold. The writer is of opinion

that, notwithstanding the tests that have been made, this difficulty can be overcome by the cyanide-of-potassium process. If the sand, after being lifted by the dredge, were passed through revolving hot-air cylinders or through a mechanically rabbled furnace, like the one recently erected at Mount Morgan for calcining mundic ores, and then concentrated by sending it to large gravitation-tables, the writer sees no reason why the cyanide-of-potassium process should not treat this golden sand successfully.

If the auriferous sand cannot be treated by cyanide of potassium, then one must turn to some other method. The "thermo-hyperphoric" process is the invention of Mr. Lockwood and the Rev. Joseph Campbell. It is both scientific and practical, and the inventors claim that they can save 95 per cent. of gold out of the Te Aroha ores, which are the most complex in New Zealand.* In this process all those base substances that prevent the amalgamation of the gold and quicksilver are eliminated by water-gas in air-tight furnaces. The water-gas is made by passing superheated steam over incandescent coke. Water is made up of hydrogen and oxygen in proportion of two of the former to one volume of the latter, and water-gas contains almost the same proportions of hydrogen and oxygen, but the oxygen is combined with carbon in the form of carbonic oxide. The chemical reaction is as follows:—Two volumes of steam and two volumes of carbon yield four volumes of hydrogen and two of carbonic oxide, but the volumes occupied by these are about equal. One hundred parts of steam, by weight, requires 66½ parts of charcoal to effect its complete decomposition and produces the two gases in equal volumes, weighing together 166½ parts. Of this mixture, 155½ parts by weight are carbonic oxide, and 11 parts hydrogen. The air-tight furnace is so constructed that this gas, as there produced, passes into and amongst the ore. It is raised to a temperature of 1,200° Fahr., and the gases which act as reducing agents eliminate all the sulphur, arsenic, antimony, zinc, tellurium, iron oxide, or any other substance that interferes with the amalgamation of the gold. This treatment will cost from 3s. to 5s. per ton. A plant to treat 100 tons per week, including pans for amalgamation, etc., will cost about £1,500.

Placer-mining.—Although this form of mining is not carried on in the North Island, there are a few localities on the Hauraki peninsula where it could be profitably conducted.

* *Trans. Fed. Inst.*, vol. xiii., page 480.

It is carried on to some extent, principally in Otago, generally by small companies and private individuals, and wherever capital and system have been introduced handsome profits have, as a rule, been the result. This is very noticeable in the case of the Blue Spur claim. Another claim to which special reference might be made is the Nokomai, the property of a Chinaman named Sew How, upon which he has spent about £15,000 in water-races and general works. The writer considers that if a number of these small claims could be amalgamated and worked by a general development company good results would be obtained.

All along the west coast of the South Island and throughout Otago there are vast auriferous deposits of quartz-drift. These deposits are almost universally horizontal, and vary in depth from 6 to 80 feet from the surface. The great difficulty in the past has been to raise the stuff requiring treatment to such a height that it could be disposed of, and quite recently a plant has been perfected which has overcome this difficulty. Water is brought on to the ground at as high an elevation as possible, and then confined in pipes, which gradually decrease in size from the intake to the foot of the workings. The water is then allowed to escape through a cast-iron nozzle of small dimensions, thus producing great force. The water escapes into a vertical pipe, which must be set perfectly plumb above the throat-piece. Just above the escape, and in the side of the upright pipe an aperture is cut, through which the dirt is blown by a separate jet of water.* Roughly speaking, an elevator of this description will raise the water and *débris* 1 foot for every 10 feet of fall. The gold is then saved on the ordinary perforated tables. This gold is in almost every case free from baser metals, and therefore requires no scientific treatment. An apparatus of this description could be used in various places on the Hauraki peninsula with profitable results.

Dredging.—Dredging for gold is an industry peculiar to New Zealand. There have been various attempts made in other countries to raise gold from the depths of the water by means of machinery, but it is here for the first time in history that this method has developed into a systematic and important industry. Stuff is raised from a depth of 50 feet, and this is by no means the limit of deep working with the improved machinery available. However, these lines are not penned with the object of describing the various evolutions which dredging has gone through, from the primitive green-hide hand-worked scoop to the colossal

**Trans. Fed. Inst.*, vol. iii., page 658.

steam bucket-dredge, which raises hundreds of tons of wash-dirt per hour, but merely to show the illimitable possibilities awaiting the systematic development of the dredging industry on an extensive scale. At the present time, there are about 40 dredges at work on the South Island, their average value being about £2,000 each. The number of men employed per dredge is about seven. The amount of gold obtained in 1895 was estimated at about 25,000 ounces, the total value being about £100,000. These figures are well within the mark, as there are numbers of small parties at work who never take the trouble to send in their gold-returns. However, taking the figures as they are, they will show how important this industry has already become, and how well it compares with any other form of gold-mining, yielding as it does over 100 per cent. on the capital invested.

The total gold-returns from the Roxburgh dredge, Otago, during the last four years are 2,722 ounces, or 680½ ounces per annum; the average per week during that time being 13⅗ ounces.

The home of the dredging industry is in Otago, although there is a little done both in Southland and on the West Coast, near the Reefton district. Little or nothing has been done in this way on the North Island, although there is ample evidence that the river-heads, flats, and sea-beaches abound in the noble metal. It must not be overlooked that large quantities of gold must have been deposited under the shallow beaches or flats and creek-beds by an extensive erosion of the surrounding country.

All the streams which have their source in the auriferous belt, which traverses the Hauraki peninsula, show strong colours in the pan; this gold has travelled from the hills and been deposited through thousands of years by flood-waters. With the everlasting erosion of ridges and spurs, and of ravines and cañons, huge quantities of gold-bearing rock must have been washed down and deposited in the creek-beds and beach-flats.

It, of course, must be borne in mind that the conditions under which this gold has been distributed in the creeks and beaches of the Hauraki peninsula are totally different from the deposits of the South Island. In the latter, the rivers are of much greater length and bear strong evidences, on an extensive scale, of ancient fluviatile action; while the streams of the Hauraki peninsula are much smaller and of a comparatively recent period.

Several dredging claims have been marked off in the North Island of late years, but as they are only starting with capitals of £500 to £1,000

the results can be easily obtained. The [illegible] Waikoweiti Extraction Company [illegible] contain large deposits of [illegible]

Cyanide-of-Potassium Process.—[illegible] the treatment of [illegible] experimental plant was [illegible] with the result that [illegible] this process. [illegible] and percolation [illegible]

The Hauraki [illegible] These ores in the past were [illegible] mation process as a [illegible] not giving half as [illegible] and more profitable [illegible] calcining the ores [illegible] substances. [illegible] tailings and [illegible] form by passing [illegible] then collected and [illegible] tailings after [illegible] Hauraki ores are [illegible] treatment that [illegible]

A test was made by the [illegible] the relative merits of the [illegible] amalgamation process, and [illegible] were subjected to the cyanide process [illegible] process, while two parcels were [illegible] copper-plates. The extractions [illegible] as follows:—Cyanide, 84 per cent.; [illegible] plates, 51 per cent.; [illegible] cyanide-of-potassium process.

During a trip through the mining centres of [illegible] writer paid a visit to the famous Mount Lyell mine [illegible] hampton, when he had an opportunity of [illegible] process as adopted by the proprietors of the above mine. The [illegible] this mine is calcined by being passed through [illegible] cylinders and the mechanically-raked [illegible] have liked very much to have given further [illegible]

briefly referred to, but as the cost of treatment absolutely precludes it from competing with the cyanide process in New Zealand, it is scarcely worth while entering into detail.

A great deal has been said about the insecurity of tenure to which the mining lessee is exposed in New Zealand. These statements are not according to fact. The government offer every inducement to those engaged in the mining industry. By the passing of the Mining Amendment Act of last year, all titles granted for mineral leases are indefeasible; and there has never been any question about those already granted by the government within the gold-fields area. What was aimed at by the introduction of the Amendment Act was to define whether the crown had power to grant mineral leases on certain freehold properties held by large timber corporations which were not being worked for minerals. These lands, if proved to be auriferous, must either be worked under the mining regulations or way made for others who are able and willing to do so. All certificates of title under the Land Transfer Act of 1877 are absolutely indefeasible.

The liberal policy of the government in dealing with every claim on its merits, such as granting permission to work these claims with fewer men than provided for in the regulations, has worked most satisfactorily.

In looking forward to the future development of the mineral resources of this country, there are nine points which claim special attention, and by which the contents of the preceding pages may be summarized:—

(1) The Hauraki district, from its geographical position and contiguity to salt-water, ensures its particular pre-eminence as regards facilities for the transportation of machinery, etc.

(2) This district from its geological formation, which is similar to that of California and other rich mining regions, gives great promise in the near future, when the work of development is fairly inaugurated, that the golden harvest which has hitherto been reaped will be overshadowed by the immense wealth which will reward the efforts of those engaged under the new condition of affairs.

(3) No gold-field in the whole world possesses better facilities for economic test and development. The country being mountainous, the mines can be worked level-free by adits, thus saving the cost of pumping machinery and winding-gear.

(4) It possesses most exceptional advantages in having abundance of

water for motive power, and an unlimited supply of timber—sawn timber costing from 6s. to 8s. per 100 feet.

(5) Freights are low and labour cheap.

(6) No topographical or climatic difficulties present themselves.

(7) With the cyanide of potassium and other modern methods for the treatment of ores, even low-grade rock can be made to pay handsome profits.

(8) The reefs are numerous and frequently of great size and richness.

(9) The mines cannot be profitably worked by individual effort or small local companies, and their development will depend, to a great extent, on the influx of outside capital.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,
OCTOBER 13TH, 1897.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting, and of the Annual Excursion held concurrently with the Edinburgh meeting of The Federated Institution of Mining Engineers, were read and confirmed.

The following gentlemen were elected :—

MEMBERS—

Mr. JAMES HOGG, Minas Aznalcollar, Seville, Spain.
Mr. DALZIEL GORDON SMITH, P.O. Box 365, Vancouver, B.C.

ASSOCIATE MEMBERS—

Mr. JAMES FERRIER, 68, Mitchell Street, Glasgow.
Mr. ROBERT HAMILTON, 18, Waterloo Place, Edinburgh.
Mr. A. G. KIRKUP, 4, Shandon Terrace, Edinburgh.
Mr. ROBERT LEITCH, Townhill Colliery, Dunfermline.
Mr. THOMAS SCOTT, St. Vincent Street, Glasgow.

Mr. WILLIAM F. LANG read the following paper on "The Brown Hydraulic System for Underground Pumping and Haulage":—

THE BROWN HYDRAULIC SYSTEM FOR UNDERGROUND PUMPING AND HAULAGE.

By WM. F. LANG.

Before proceeding with a description of the Brown hydraulic system, the writer wishes it to be clearly understood that in none of its vital parts is it altogether new or untried. The main novelty consists in its adaptation to mining purposes, and possible users need not fear that they are pioneering, or experimenting with an intricate and troublesome gear which perhaps no one but the inventor can fully appreciate. The writer is satisfied that a very cursory inspection of its details and working will satisfy most practical engineers both as to its simplicity and its efficiency. The hydraulic distributing-valve, which is the most important detail of the whole plant, has for many years been used successfully in hydraulic installations on board ships of the highest class for steering, hoisting, and other purposes, and has proved itself capable of long continuous use without serious deterioration. The writer mentions these facts in order to show that although hitherto the system has not been largely adopted for mining purposes, it has long ago proved its efficiency under quite as trying circumstances.

The inventor was first induced to take up the subject of hydraulic pumping in mines through being consulted on this point by the Shotts Iron Company, who were experiencing considerable trouble in the Burghlee pit, Loanhead, where they had an installation of steam-driven pumps for draining the mine.

The main incline or shaft at Loanhead colliery has an average gradient of about 50 degrees, and a vertical depth from the surface of 1,560 feet. The water is pumped to a level about 990 feet above the bottom of the shaft. Three stations for steam-pumps were formed in the shaft, each pump raising the water about 330 feet to the pump next above it. There is also another steam-pump about 1,000 feet from the bottom of the shaft, the gradient to where it is placed being 1 in 8. In addition to these four pumps, and adjacent to the pit-bottom, there is a 16 inches haulage-engine for working the main dook. It will be evident that the heat-radiation from cylinders and

steam-pipes, and the constant condensation taking place in the same, in spite of all possible precautions, had combined to produce a very unsatisfactory condition of matters in the pit. Under such circumstances, the directors of the Shotts Iron Company turned their attention to hydraulic pumping, etc., with the result that Messrs. Brown Brothers were ultimately entrusted with the erection of the hydraulic plant presently at work.

The plant eventually supplied for underground operations included the main pump, placed at the bottom of the shaft, capable of raising 300 gallons of water per minute to a vertical height of 990 feet in one stage; a hydraulic motor fitted to the haulage-machinery in place of the steam-engine which was removed, the position being about 360 feet from the main pump; a smaller pump having three single-acting plungers, 4¼ inches in diameter, placed about 1,000 feet from the main pump; and another similar set of pumps placed about 3,100 feet from the main pump. The power-water is conveyed from the pumping-engine to the pumps in hydraulic tubes, 4 inches in diameter, which diminish to tubes, 1½ inches in diameter, for driving the last pump. The return main to the supply-tank for the exhaust-water is 4½ inches in diameter.

The pumping-engine aboveground is high-pressure, compound, and of vertical type, having steam-cylinders 19 and 30 inches in diameter, by 24 inches stroke, and the boiler-pressure is 100 pounds per square inch (Figs. 1, 2, and 3, Plate I.).

The pumps, which are of the wellknown bucket-and-plunger type, to give a continuous flow of water, are 5 inches in diameter, attached directly to the piston-rods of the engine, and capable of supplying water at a pressure of 1,000 pounds per square inch. The whole of the machinery is fitted to a heavy cast-iron bed-plate, and as all strains due to work being performed are self-contained, no heavy foundations are required for the engine. All pumping-rams on the engine and underground pumps are of gun-metal, and the engine is automatically controlled by special appliances which prevent racing, should a pipe burst or a joint give way, and which also stop the engine should the pressure in the power-pipes rise to any extent, on account of the pumps in the mine being stopped suddenly. The discharge-pipes from the power-pumps are also fitted with a bye-pass arrangement which permits of the engine being started free of load, and of the load being gradually applied whilst the engine is running. A very complete system of lubrication is provided, and the machinery can be run continuously with minimum attention.

What has just been said describes briefly the conditions under which this plant is working at Loanhead, but given a sufficient supply of power-water at a pressure of 1,000 pounds per square inch, these pumps can be applied against much greater heads than 990 feet. For instance, in the Loanhead pump, the power-rams are 5¼ inches in diameter, and the pumping-rams 6⅜ inches in diameter, but it would be perfectly good practice to have the power-rams of such area as would enable them to drive the pumping-plungers against a pressure in the rising-main equal to that of the power-water, viz., 1,000 pounds per square inch, or even greater, all the valves, both in the power-pumps and mine-pumps, being of the same dimensions and patterns. These valves are of conical type, made of bronze, are of small diameter, and are used in groups.

The pump at Loanhead is arranged for two sets of double-acting plungers, 6⅜ inches in diameter, driven by motor-rams 5¼ inches in diameter, all fitted to two separate soleplates fixed parallel to each other, each set being connected to a double-throw crank, by means of which the distributing-valve is rotated, and the stroke of pumps completely controlled.

Whilst this arrangement works very well, experience has led to the adoption of three single-acting pumping-rams in preference to the pair of double-acting rams, the former being more easily controlled and capable of being driven either at a faster or a slower speed.

Coming now to speak generally on the Brown hydraulic system, and taking engines and power-pumps first into consideration, the writer need scarcely remark that there should be no hard-and-fast rule as to design, save that they must be capable of giving an ample and steady supply of power-water at the required pressure of 1,000 pounds per square inch. Mr. Brown's long practice as an hydraulic engineer, however, had led him to adopt a compound surface-condensing engine, having two cylinders 16 and 26 inches in diameter by 20 inches stroke, very similar to the engine erected at Loanhead, but provided in addition with a steam-accumulator which is very useful where intermittent working of the underground plant is unavoidable. This accumulator acts as an efficient governor to the engine, and with the other safeguards formerly mentioned any accident through a run-away is scarcely possible.

The power-pump barrels are of cast-iron or steel, and are supplied through the suction-pipes from a water-tank raised high enough above the ground to ensure an inflow of water to the pumps. The main power-pipe is led direct from the pumps to the farthest point, where duty is

required, and between these points any requisite number of pumps or motors may be connected to it. The return-main extends from the farthest station underground and delivers the return-water into the tank already referred to. The bye-pass arrangement for relieving the engine of load when being started is also connected to this tank, so that there is no loss of power-water through its use.

Hydraulic Pump.—Figs. 4 and 5 (Plate I.) show a small set of three-throw single-acting pumps of plunger type, as supplied to the Shotts Iron Company. The motor ram-barrels and pump-barrels and frames are made in one casting, the rams being made of gun-metal. The whole arrangement of parts is as simple as possible. The rams of the motor-cylinders are $1\frac{7}{8}$ inches in diameter, and the pump-rams are $4\frac{1}{4}$ inches in diameter. By another arrangement not shown on the drawing, balance-cylinders are provided, by which means the crank-shaft is relieved of all strains due to the returning of motor-rams against heavy statical pressure when the pumping is against a great head. The power-water is introduced to the valve-casing through the branch-pipe *A* which is connected to the power-main. This casing has also three branches, *B*, *C*, and *D*, for connecting each of the three motor-cylinders. There is also a fifth branch *E* on the casing, through which the exhaust-water is passed to the return-main after completing its work in the motor-cylinder. The valve itself is simple, being a plain bronze ring of suitable diameter and depth, slipped on to an eccentric collar formed on the short shaft, which is a continuation of the crank-shaft, and is joined to the same by a pair of adjustable flange-couplings. The eccentric collar, when the shaft is revolved, moves the valve or ring, the edge of which works on the valve-face in such a way that it alternately exposes the ports in the valve-face which communicate with each of the three branches leading to the motor-cylinders. The power-water is admitted to the ports in the valve-face, wholly from the outside of the ring, for the forcing-stroke of the motor-rams; on the return stroke, the water is forced back through the same pipe as that which admitted it, but from the changed position of the valve or ring the port in the face is now inside the same and in direct communication with the return main, the whole action of the valve dealing with the power-water being very similar to that of the ordinary slide-valve when dealing with steam. The peculiar motion of the valve working against the face ensures a perfect bearing-surface being maintained, the valve-faces being improved after working.

Both the suction and discharge-chests are similar so far as the arrange-

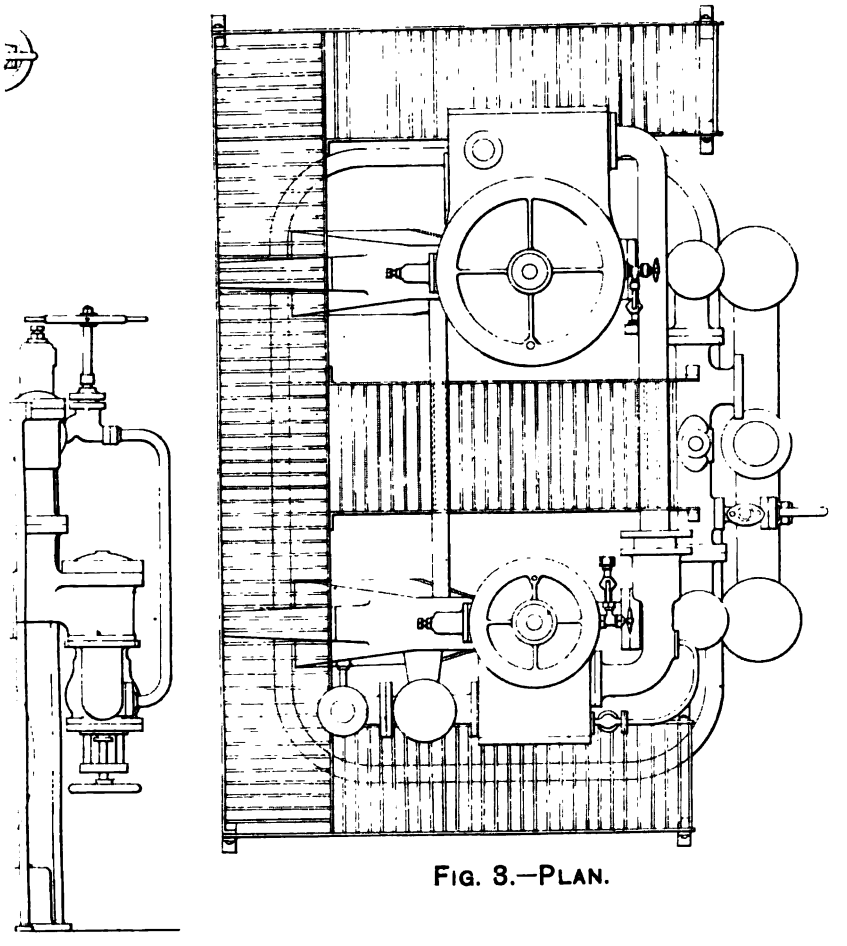


FIG. 3.—PLAN.

N.

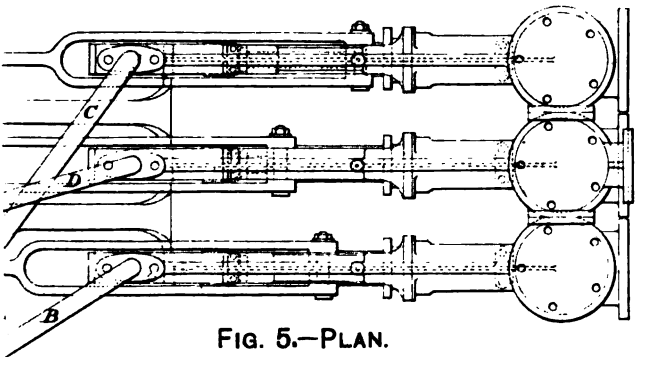


FIG. 5.—PLAN.

ments of the valves are concerned: the valves used throughout being of conical type. In the larger pumps, the valves are kept of the same size but fitted in groups on each chest. The bearing-face on the valve-seat is practically a knife-edge, and the face on the valve is spherical, allowing for a slight canting motion when working, which, along with the rotary motion it is free to take, effectually prevents uneven or great wear of surfaces even under very high pressure.

Tests in the makers' works showed the efficiency of this pump to be about 55 per cent. of the indicated horse-power, but the Shotts Iron Company obtained somewhat better results in actual working.

This pump can be run at any speed up to 100 feet per minute of ram-travel without undue knocking or apparent straining.

Haulage Motor.—In the arrangement at Loanhead, the three motor-rams are fitted into a triangular cast-iron frame and surrounding the main shaft, on the outer end of which is keyed a spur-pinion working into a spur-wheel which is keyed on to the drum-shaft. On the other end of the shaft, and in the same plane as the motor-rams, an eccentric or crank is formed upon which, and acting through anti-friction rollers, the motor-rams exert pressure imparting a rotary motion to the shaft, and by means of the gear-wheels at the other end to the haulage-drum.

The same form of rotary or distributing-valve is used, and similar connections are made to the power and return-mains as in the pumping arrangement, the valve being rotated from the crank-shaft by means of spur-gearing. The valve-shaft is provided with a hand-wheel and suitable stops, allowing it to be turned back a certain distance in the opposite direction to that in which it is being driven at any time. This turning back alters the position of the valves in relation to the ports in the valve-face, and thereby reverses the action of the motor-rams.

Mr. J. M. Ronaldson (H.M. Inspector of Mines) remarked that Mr. Lang stated that the pump was capable of forcing water against a lift of more than 900 feet, and asked whether that had been tested in practice? It had been found by experience that hydraulic pumping-engines (such as the Moore pump), although shown theoretically to be capable of forcing water to a great height, did not give high results in practice when very high lifts were attempted.

Mr. Robt. Martin (Portobello) agreed with Mr. Lang that, except for very short distances, steam should not be taken into a mine, and that hydraulic pumping was well adapted to meet the exigencies of the most extensive or fiery mines. The hydraulic power-conveying pipes occupy little space, and can be placed in either the upcast or downcast shaft. There is no inconvenience from heat or condensation, and there is greater economy. The power-water pipe in this case is 4 inches diameter and the return or exhaust-pipe to the surface is 4½ inches in diameter; was there any advantage in using a return-pipe of larger diameter? Mr. Lang stated that the power-pumps "are of the wellknown bucket-and-plunger type," but he thought, under high pressure and after some wear-and-tear, that this type of pump is very guilty of allowing "slip" to occur, and is not so easily kept in good order as the ram type. Could Mr. Lang give the speed of the engine, and the quantity of water passed through the power-pipe? The motion of the water in the power-pipe is not "continuous" as stated in the paper. Mr. Lang also stated that "the power-water is admitted to the ports in the valve-face, wholly from the outside of the ring, for the forcing-stroke of the motor-rams; on the return stroke, the water is forced back through the same pipe as that which admitted it, but from the changed position of the valve or ring the port in the face is now inside the same and in direct communication with the return main." The action here is exactly similar to that of a reciprocating-pump, the returning ram having to force the power-water "back through the same pipe" against the load in the main return-pipe. Every objection to a reciprocating-pump is applicable to this pump, with the addition of possible throttling in the valve-passages. The pressure required in the power-water is vaguely stated as 1,000 pounds per square inch. The actual maximum and minimum pressure in the power-water pipes, in the forcing and returning branch-pipes, and in the return-mains should also be given. Mr. Lang says that "it would be perfectly good practice to have the power-rams of such an area as would enable them to drive the pumping-plungers against a pressure in the rising-main equal to that of the power-water . . . or even greater." He dissented from that opinion, as the general idea of hydraulic practice is to use a small quantity of water at a high pressure to pump a larger quantity at a lower pressure. In the case of Loanhead, if the pumping-head was equal to 1,000 pounds per square inch instead of only 425 pounds, as it is, the area of the power-rams would require to be fully twice that of the pumping-rams, and the water required to drive the power-rams would be fully double the quantity pumped from the pit, modifications which

would involve the use of a larger steam-engine and hydraulic plant. The "distributing-valve" seems to be kept on the face with difficulty, and this may be due to the force of the returning or exhaust water. The bye-pass arrangement, "which permits of the engine being started free of load," can be attached to any hydraulic arrangement.

Mr. J. S. DIXON (Glasgow) said that, as regards hydraulic pumps, his experience coincided with that of Mr. Ronaldson. In his experience, hydraulic pumps on the Moore system, when applied beyond a lift of 420 feet, did not give satisfactory results. If Mr. Lang could apply the hydraulic system to haulage as well as to pumping, the mining community would owe him a very deep debt of gratitude. He did not know whether it had been tried practically or not, but the difficulty he had always foreseen in applying hydraulic power to that purpose was how to regulate it to varying loads; if the pressure was 1,000 lbs. per square inch, and if they had a varying load requiring, say, 50 horse-power at one time and 100 horse-power at another, how could the motor be regulated without a great waste of water?

Mr. J. GILCHRIST (Cumnock) asked Mr. Lang to supply particulars of the actual work done at the Loanhead colliery. He had seen the plant about 12 months ago, and was satisfied with the results, more especially as they were able to use the power-water to drive a haulage-motor, and small pumps in the workings.

Mr. ROBERT MARTIN, replying to Mr. J. S. Dixon, stated that the Moore hydraulic pump was giving excellent results at the Niddrie collieries, and working against a head of 660 feet.

Mr. J. GILCHRIST said that the Moore hydraulic pump might pump efficiently over that distance; but the difficulty was, when they carried the power-water, say 3,000 feet, into the workings, they had so long a column of compressed water, and the chances were that they could not move the pump in the mine: that was, they did not get the corresponding stroke underground that they had on the surface. In one case, where he proposed to adopt the Moore hydraulic pump, he was informed that there was a limit to the distance the motor-pump could be placed from the power-pump.

The PRESIDENT asked whether it was not the case that, even in vertical shafts, it was not desirable to force against a head of more than 480 feet? It was found by experience that the Moore hydraulic pump did not work satisfactorily over that head.

Mr. R. MARTIN said that, if the power-pump on the surface was large enough, they got the full stroke of the pump in the mine. The vertical head at Niddrie colliery was 660 feet on a slope of 50 degrees, and the engine on the surface was 2,525 feet from the pump in the workings.

Mr. W. F. LANG, replying to the discussion, said that the Brown hydraulic pump had not yet been applied against a greater head than 990 feet, but pumps with similar rams and valves, had long been worked, supplying power-water at pressures up to, and beyond 1,000 lbs. per square inch. At Loanhead collieries, the power-pumps attached to the steam-engines are quite similar to the underground pumps, with the exception of the rams, which are 5 inches in diameter on the pumps aboveground, and $6\frac{3}{8}$ inches in diameter on the pumps underground. These power-pumps have been working for $3\frac{1}{2}$ years on pressures representing heads averaging from 1,800 to 2,200 feet.

There is no necessity for the return-main to be larger than the power-main, save that less power is required to pass a given quantity of water through a large pipe, than to pass the same through a small pipe, and consequently, the return-main, in all cases, is made larger than the power-main.

The bucket-and-plunger type of rams work satisfactorily, and are best suited for double-ram pumping-engines, where a continuous discharge is desirable: at the same time, it is quite true that they require attention. In his (Mr. Lang's) paper he stated that the pumps were preferably made with three single-acting plungers, which gives quite as steady a discharge, and are free from the objections that can be urged against the bucket-and-plunger type.

The speed of the engine is manifestly regulated by the duty being performed by the several machines at work. The average speed at Loanhead collieries is about 48 revolutions per minute, but on occasion they have been run at 80 revolutions per minute.

If these pumps were made with only one motor-cylinder, Mr. Martin might be justified in asserting that the flow in the power-main was not continuous, and that this type of pump was open to all the objections that could be urged against a pump driven by double reciprocating power-mains. As, however, every pump has not less than three motor-cylinders, of which one or more is always freely open to the power-main, the flow in the same is continuous, and always in one direction. As the pressure in the main does not vary more than $2\frac{1}{2}$ per cent, it is clear, also, that there is no throttling in the valve-passages, or pipes, connecting the motor-cylinders to the valve-casing.

The Loanhead engines are capable of supplying power-water at a pressure of 1,000 lbs. per square inch. The usual working pressure is 800 lbs., and the variation in pressure, from the highest to the lowest reading, is about 20 lbs. There is a somewhat similar variation of pressure in the rising main.

He had already given reasons for claiming that the Loanhead pump was suitable for forcing against much greater heads than 990 feet. Mr. Martin stated that if a pump of this type had to work against a static pressure of 1,000 pounds per square inch, it would be necessary to have the power-rams fully twice the area of the pumping-rams. This was not his (Mr. Lang's) experience from tests that had been made, neither could it have been Mr. Martin's experience when testing the Moore hydraulic-pump at Niddrie colliery, as he had seen it stated that the efficiency of this pump was 75 per cent. of the indicated horsepower of the engine, allowing, therefore, just 25 per cent. for loss of power due to friction of engine, gearing, power-pumps, power-pipes, motor-rams, pumping-rams, etc. If such results were got at Niddrie colliery, where the friction of the whole plant had to be allowed for, it was scarcely reasonable to assert, even under the conditions named, that a pump of the Brown type would require to have the motor-rams of fully twice the area of the pumping-rams, especially as only the friction of the two rams was involved, and probably an excess in area of 40 per cent. would be found very ample. The distributing-valve has no tendency to leave the valve-face.

Attention had been called by Mr. Dixon to the fundamental and only disadvantage of transmitting variable power by water-pressure, and numerous devices had been introduced to overcome this defect, particularly in rotary-engines. Mr. Brown, about twenty years ago, patented a hydraulic hoisting or haulage-winch, in which the stroke of the engine could be varied, whilst in motion, to meet the demands of power necessary to deal with varying loads. This machine was described in a paper, read before the Institution of Naval Architects, on "Applications of Hydraulic Machinery."* Whilst such devices are theoretically warranted, it is yet a question whether the additional complication results in any practical saving, as the cost of supplying power-water is comparatively small. In all the installations for distribution of power in docks, railway-stations, or by hydraulic-power companies in our chief cities, no real attempts have been made to adjust the supply of power-water to the power required, because simplicity of machinery is the chief consideration, and the advantages of the hydraulic system are admittedly so great notwith-

* *Trans.*, 1884, vol. xxv., page 153.

standing the defect alluded to by Mr. Dixon. At Loanhead collieries, where a haulage-engine had been working for three years, no variable stroke arrangement was applied, but the engine was designed to as nearly as possible develop the average power required.

An addition had been made to the plant at Loanhead colliery in the form of a single cylinder hydraulic-hoist used for charging an ironstone calcining-kiln. The load is raised to a height of 45 feet, and by an ingenious arrangement is automatically tipped into the kiln. This elevator had been designed and made by Mr. Love, the manager of the works. The hoist is worked from the power-main, a connexion being made close to the pumping-engine.

The average speed of the pumping-engine is about 48 revolutions per minute, and as all work at the colliery is double-shifted, they run night and day. Connected to the power-main are the undernoted machines, viz.:—

(1) The main-pump at the bottom of the shaft, the average work being 150 gallons per minute raised to a height of 990 feet.

(2) The haulage-motor, placed at a distance of 360 feet from the main-pump, works a tail-rope haulage from a dook fully 3,000 feet long, having a gradient of about 1 in 12. The usual load is 12 hutches of ironstone, each hutch having a gross weight of 15½ cwts. The speed of travel is about 5 miles per hour.

(3) A smaller set of pumps in the dook, placed about 1,000 feet from the main-pump, forces from 70 to 80 gallons per minute through 1,000 feet of pipes against a head of 130 feet.

(4) Another similar set of pumps, placed in the dook, at a distance of 3,100 feet from the main pump, forces from 70 to 80 gallons of water per minute through 3,100 feet of pipes against a head of about 150 feet.

(5) Lastly, the single cylinder hydraulic-hoist for kiln-elevator, raises a load, including the cage, etc., of about 25 cwts. at a speed of about 70 feet per minute.

The following paper by Mr. W. J. Orsman, on "Some Defects in Gunpowder as a Blasting Agent," was read:—

SOME DEFECTS IN GUNPOWDER AS A BLASTING AGENT.

By W. J. ORSMAN.

Since the issue of the Home Secretary's order prohibiting the use of gunpowder in certain mines after January 1st, 1898, several proposals have been made to advocate the use of a better class of powder called high-grade gunpowder, in which the saltpetre, sulphur, and charcoal shall be intimately mixed together in proportions which are chemically complementary to each other, that is to say, there shall be a sufficiency of saltpetre to supply the oxygen necessary to completely burn up all the carbon and sulphur.

In low-grade gunpowder we find the same materials, but in different proportions. Further, the ingredients may probably be of inferior quality, and less carefully milled. Seeing, then, that the difference between high and low-grade powder is only one of degree, it is necessary first of all to determine what the dangerous properties really are. We shall find that the dangers lie principally with the heated products of combustion, and secondly, with the inflammable character of the gaseous portion.

Sir Frederick Abel, and Captain Noble found the following results when testing mining-powder:—(1) The temperature of explosion is about 2,000° Cen^{t}.; (2) the products of combustion are 51·35 per cent. gaseous, 47·04 per cent. solid, and 1·61 per cent. water-vapour; (3) the solid products are in a state of fusion and occupy $1\frac{3}{4}$ minutes in solidifying.*

From the above results we see that nearly half the weight of the products of combustion consists of solid matter, which at the moment of explosion may be projected into the air of a mine at a very high temperature, namely, 2,000° Cent., and according to Mr. D. M. D. Stuart's calculations, if the powder be confined the temperature reaches 2,896° Cent.† Further, the excess of charcoal in mining-powder produces the poisonous and explosive gas—carbon monoxide, and a mixture of this gas with air and coal-dust can easily be ignited and initiate a disastrous explosion. In this way, mining-powder has been responsible for several accidents in dry and dusty, though distinctly non-gaseous, mines.

* *Philosophical Transactions of the Royal Society of London*, vol. 171, page 203.
† *Coal-dust, an Explosive Agent*, page 37.

The excess of charcoal in mining-powder has the effect of lowering the temperature of explosion, in consequence of the want of oxygen and formation of only partly oxidized gaseous products. If we increase the amount of oxygen by the addition of more saltpetre the effect is to form fully oxidized gaseous products, but with an increase of temperature. This is what is proposed to be done in producing high-grade gunpowder, and we shall have a gunpowder which may produce 30 per cent. less carbon monoxide and other inflammable gases, but the total solid products will be increased, and the temperature will be much higher, as has been proved by Messrs. Abel and Noble.

The following table shows the results obtained at Woolwich by Messrs. Abel and Noble with different grades of gunpowder :—

Gunpowder (1 gramme).	Units of Heat.	Cubic Centimetres of Permanent Gases.
Sporting	764·4	241·0
Fine grain	738·3	263·1
R.L.G.	725·7	274·2
Pebble	721·4	278·3
Mining	516·8	360·3

Messrs. Abel and Noble then state :—

It will be seen that the order of decrease of units of heat is that of increase of volume of permanent gases; and the products of heat units by gas-volumes do not differ greatly from a constant value. This points to the conclusion that the pressures at any given density of charge, and the power of doing work of the various powders, are not very materially different: a conclusion verified by experiment for the three Waltham Abbey powders, and in a less degree also for the other powders.*

In view of the above statement, it would appear that there ought not to be much difference in total power produced by mining-powders having different proportions of ingredients. The varying results obtained from the mortar tests may be accounted for by the ingredients being badly incorporated, and the bullet being projected before the powder has had time to completely burn.

With high-grade gunpowder, however pure the ingredients may be, and however well they may be incorporated, we are still faced with the danger, which seems to be ignored by those who have written on the subject, of the enormous amount of incandescent solid matter which is liable to be projected into the air of a mine. On explosion, half the weight of the explosive is transformed into smoke, which consists principally of various salts of potassium, due to the presence of saltpetre. These particles being projected at a high temperature into the air cause

* *Dictionary of Applied Chemistry*, by Dr. T. E. Thorpe, 1891, vol. ii., page 63.

flame, and must be dangerous in the presence of explosive mixtures of gas or dust, and whether high or low-grade powder be fired in a mine, flame is invariably seen. A very instructive experiment is to cover a cartridge of gunpowder with a heap of coal-dust. On firing the powder, the dust is scattered in all directions, catching fire and burning with an enormous volume of flame; while the nitrate-of-ammonium explosives under similar conditions do not show a sign of flame.

In the nitrate-of-ammonium explosives, we have the more rapid form of explosion called detonation taking place, and the products of explosion are entirely gaseous. With roburite, for example, we find that 60 per cent. by weight of the products consist of gases which are not dangerous in any way, and 40 per cent. of water, which, at the moment of explosion, exists as steam. The theoretical temperature of explosion, calculated on the basis of the mean specific heat of the products of combustion, is stated to be from 2,000° Cent. to 2,200° Cent.; but it is probably much lower as we find that the practical is always lower than the theoretical temperature. For instance, with gunpowder the calculated temperature is 2,896° Cent., whereas the actual temperature is about 2,000° Cent.

Another point in favour of nitrate-of-ammonium explosives is that, being so much stronger than gunpowder, less weight is required to do the same amount of work, and, therefore, the total heat developed would be much less. From actual experiments made during the last 7 years, working with roburite and gunpowder side by side in the same seams and under similar conditions the following results have been obtained:—

In the Durham and Northumberland districts, the average results from experiments at 7 different collieries in coal and stone show that the comparative strengths of gunpowder to roburite are as 1 to 3·01. In the Cumberland district, the average from 4 collieries gives 1 to 3·05. In Derbyshire and Yorkshire, the average from 17 collieries is 1 to 2·89. In Scotland, 87 experiments, occupying 9 days, were made in brushing rock mixed with metal from 2 to 4 feet thick, and the average worked out in the proportion of 1 to 3·24.

In general terms, it may be taken that the comparative strengths are:—In coal, 1 of roburite equals 2½ of compressed powder; and in rock, 1 of roburite equals 3 of compressed powder. If, then, it is only necessary to use 1 ounce of roburite for every 2½ ounces of mining-powder, it stands to reason that the total quantity of heat developed will be much less in the case of the former.

Further, with nitrate-of-ammonium explosives we have the flame-

quenching properties in the explosive itself, since nearly half the weight of the cartridge is converted into steam, owing to the presence in the nitrate of ammonium of the elements which go to form water.

Many attempts have been made to disparage the value of the experiments made by Mr. H. Hall in the disused shaft at Skelmersdale, one of the principal arguments being that the cannon was vertically suspended at the bottom of the shaft, its axis corresponding with the axis of the shaft, and in consequence that the heat was diffused over too great an area to cause ignition of coal-dust when safety explosives were fired, whilst with the slow burning mining-powder ignition of the dust was a frequent occurrence when at rest on the sides, the air in the shaft being quite free from suspended particles. With regard to this theory, Mr. D. M. D. Stuart stated that :—*

> The roburite and ammonite undergoing detonation propelled their products at a velocity greatly exceeding that of the mining-powder, which necessarily disallowed of equal lateral expansion in the vicinity of the muzzle of the cannon, and which caused them to pierce through the dust-cloud to the much greater height, due to the larger initial velocity. The heat therefore passed through the coal-dust, with a rapidity which would not permit chemical action to be initiated, and being diffused through a considerable height of the shaft, and consequently a much greater volume of dust-cloud, was dissipated, and the coal-dust was not ignited.
>
> The difference in the behaviour of these explosives was therefore due to the great disparity in the volumes of dust-laden air, in which their products of combustion surrendered their heat. With mining-powder, the velocity of propulsion from the cannon allowed the heat to be concentrated in a limited volume of dust-laden air, and its application to the particles of coal for a sufficient period to initiate chemical actions. With roburite and ammonite, the higher velocity of propulsion due to their detonation or instantaneous generation of heat, diffused that heat through a much greater volume of dust-laden air, and did not permit contact with the particles of coal of the necessary duration to institute chemical actions before the temperature of distillation was broken down.
>
> If the conditions of these experiments compared with the conditions of shot-firing in mines: then on the question of the initiation of chemical actions in the coal-dust only, the "high explosives" would be the safer to use; but they cannot be so compared. . . . If charges of mining powder, roburite, and ammonite, were fired as in ordinary mining operations, and in corresponding positions, so that their products of combustion were propelled against opposing surfaces in the vicinity of the shot-hole, and those products contained equal quantities of heat; identical effects upon the coal-dust upon these faces must follow.

To the writer's mind, this argument is altogether wrong, and safety explosives fired as Mr. Stuart suggests (in fact, as they are fired day after day) would not and do not produce the same effects as gunpowder, for the reason that, apart from any difference of temperature, the

* *The Origin and Rationale of Colliery Explosions*, page 126.

nitrate-of-ammonium explosives are smokeless. The value of a smokeless explosive can be easily demonstrated by substituting nitrate of potassium for the nitrate of ammonium in, say, roburite. A detonating explosive is obtained of great power, and the products are propelled with a velocity equal to that from nitrate-of-ammonium explosives, but instead of being entirely gaseous, solid particles due to the saltpetre, as in gunpowder, are present, and such a mixture invariably sets fire to coal-dust when fired from a cannon suspended vertically.

For the above reasons, the writer is convinced that the substitution of high-grade for low-grade gunpowder would not guarantee the degree of safety necessary in the working of coal-mines. A certain advantage might be gained by diminishing the amount of noxious gases, but the presence of solid matter at an increased temperature is an element of danger liable at any moment to cause serious disaster.

DISCUSSION ON MR. A. F. HARGREAVES' PAPER ON "HIGH-GRADE GUNPOWDER;"* AND ON MR. W. J. ORSMAN'S PAPER ON "SOME DEFECTS IN GUNPOWDER AS A BLASTING AGENT."†

Mr. HARGREAVES said that Mr. Orsman's paper was a pure criticism on his paper on high-grade gunpowder. So far as gunpowder manufacturers were concerned, they made no attempt to disguise the fact that gunpowder, like all other explosives, necessarily produced high temperature, and in this respect they greatly differed from the manufacturers of the nitrate-of-ammonium explosives who had attempted, but unsuccessfully, to make out a very low temperature for roburite. It would be noticed that at the end of his paper he had given a table of the temperatures developed by all the various explosives, all of which, with one exception, had been determined by authorities of the highest standing. This was especially the case with gunpowder, and the figure of 2,200° Cent. was now accepted as being correct. The one exception to which he referred was that of roburite, and he (Mr. Hargreaves) challenged Mr. Orsman to quote a single authority giving the actual determination of the temperature developed by roburite.

In a lecture given at Nottingham, in 1893, Mr. Orsman stated that the temperature of roburite was 2,100° Cent., and this figure seems to

* *Trans. Fed. Inst.*, vol. xiv., page 2. † *Ibid.*, vol. xiv., page 57.

have been more or less accepted as representing the temperature of roburite; but he had recently reduced the temperature to 1,800° Cent., giving as his reason that the composition of roburite No. 3 was different from roburite No. 2. This, however, was not the case, as in 1893 roburite was certified as containing 87½ per cent. of nitrate of ammonium, and in the recent list of permitted explosives (which is now extinct) the composition is given as, minimum, 86 per cent., maximum, 89 per cent., or a mean percentage of 87½. The reduced temperature, therefore, cannot be accepted on the mere authority of Mr. Orsman, and no doubt he himself would be the first to acknowledge that it should not be so accepted. But, even taking Mr. Orsman's temperature of 2,100° Cent., it would be difficult to prove that roburite, with its 2,100° Cent., is an exceedingly safe explosive, and gunpowder, with its 2,200° Cent., is a very bad one. To claim for an explosive high dynamical power and little heat is not unlike running with the hare and hunting with the hounds. Prof. Berthelot, than whom we have no greater authority on explosive compounds, states that there are three conditions essential in an explosive:—(1) The formation of a large volume of gas; (2) great amount of heat; and (3) rapid chemical transformation.

Roburite had been treated in the fixing of the charges fired, in the experiments of the committee of the North of England Institute of Mining and Mechanical Engineers, as if it were really a high explosive, like dynamite or blasting-gelatine, but this was not the case. This could be demonstrated in several ways: firstly, by comparison, it was certainly not stronger than carbonite, and it was an admitted fact that the strength of the nitro-glycerine explosives was proportioned very nearly to the amount of nitro-glycerine actually present. Carbonite contained 27 per cent. of nitro-glycerine, and its strength would not, therefore, be much more than one-third that of dynamite of 75 per cent. If, therefore, carbonite was of about the same strength as roburite—and experience showed that it was not very different—it was not more than one-third that of dynamite, and, therefore, to test roburite with so small a charge as 1¼ ounces, and, because it passed the test, to proclaim its virtues, was ridiculous. At the end of his (Mr. Hargreaves') paper, the members would find a comparison of the relative strengths of gunpowder compared with carbonite and roburite, calculated from a number of actual tests made in coal-mines under the auspices of the Mining Institute of Scotland; and if they would examine them, they would find that these explosives did not differ very much from gunpowder of high quality.

It had been estimated that there were 20,000,000 shots fired annually

in the coal-mines of Great Britain. At least 90 per cent. of these shots were undoubtedly those of gunpowder, and the other 10 per cent. could be divided amongst the so-called permitted explosives (for the moment extinct) and other high explosives. The statistics collected by Mr. Stuart from the official reports of H.M. Inspector of Mines for the last 10 years, and which, he was pleased to note, Mr. Orsman had not presumed to question, showed that for gunpowder 1 death had occurred for each 1,000,000 shots fired; for permitted explosives, 1 death for every 147,000 shots fired; and for other high explosives, 1 death for every 29,000 shots fired.

Mr. GILCHRIST asked Mr. Hargreaves whether any application had been made with the view of getting high-grade gunpowder tested by the Home Office, at their experimental station.

Mr. H. A. KROHN (London) said that Mr. Hargreaves' paper divided itself really into two main points—the one a defence of the present commercial gunpowder, which he stated to be equal in safety, if not superior, to any other explosive; and the other a statement of the merits of high-grade gunpowder, which it was proposed to introduce, and which, he said, would be greatly superior to the present blasting-powder. The second point was really a chemical and theoretical question, as the promised high-grade powder was not yet in existence, and as such had been discussed by Mr. Orsman.

Mr. Hargreaves complained that high-grade powder had been refused admission to the "permitted list." It was a mistake to suppose that the explosives already on this list had a monopoly, as they, in common with all others, were to be subjected to the Home Office tests, and Mr. Hargreaves had only to send in samples of high-grade powder, and, if it passed the tests, it would be forthwith included in the "permitted list."

Mr. Hargreaves' arguments might be summed up in the assertion that in the last 5 years, with a consumption of 10 per cent. of high explosives as against 90 per cent. of gunpowder, high explosives had caused 25·33 per cent. of the deaths in handling, and 69·66 per cent. of the deaths by explosions of gas or coal-dust due to shot-firing. These statements raised an entirely false issue, as Mr. Stuart's report and Mr. Baldwin's letter (upon which these statements were based) would never have been written but for the Order in Council under the Coal-mines Regulation Act, 1896, by which certain "safety high-explosives" were placed in a preferential position not only to gunpowder but to other high explosives, such as dynamite, etc. What Mr. Stuart had done and

what Mr. Hargreaves had to a certain extent followed, was to draw a comparison between gunpowder and all high explosives lumped together, whereas the issue really lay between "permitted explosives" on the one side and gunpowder as well as the rest of the high explosives on the other.

The percentages of consumption of high explosives and gunpowder were arbitrary and incorrect, being based on an estimate made in the county of Northumberland for 1896, and on a statement made by Mr. Stokes in his report for the Midland mines inspection district for 1890. No doubt Mr. Stokes' figures were correct for 1890, as at that date not a single accident with permitted explosives had occurred in the Midland district, and only 1 in the whole kingdom. Since then the consumption of safety-explosives in the Midland district had increased to such an extent that Mr. Stokes reported in 1896 that the greater part of the mines in his district were already complying with the requirements of the Explosives in Coal-mines Order, 1896. In the South-western district, Mr. Martin reported that safety-explosives provided 40 per cent. of the shots fired in 1896. In the Manchester district, the proportion was 70 per cent., while it was wellknown that in the Liverpool district every colliery of any importance used "permitted explosives." From these facts it was safe to assume that the consumption of permitted explosives throughout Great Britain was much higher than 10 per cent. of the whole. The importations alone of such explosives in 1896 were sufficient for 10 per cent. of the 20,000,000 shots said to be fired annually, and in addition there was the home production of four or five factories.

The actual proportion of deaths due to the handling of high explosives in the last 5 years was 28 per cent., and of these, permitted explosives were only responsible for 12 per cent. From gas or coal-dust explosions, out of 395 deaths reported, high explosives had caused 290, or 73 per cent. The members would be aware of the fallacy of computing the dangerousness of an explosive from the number of deaths alone, as the 290 deaths occurred in a single explosion at the Albion colliery. The Camerton, Timsbury, Blackwell, and Brancepeth were all precisely similar explosions, due to gunpowder, save that they occurred at night when few men were in the mines, and consequently they cost only 36 lives in all. Had they occurred during the day the loss of life would have been much greater, as the explosions swept along all the main roads and caused as great structural damage and pecuniary loss as at the Albion colliery. Were the members to measure the comparative risk in these years by the number of deaths, *i.e.*, 290 to 36, or, say, 8 to 1 in

favour of gunpowder; or by the number of explosions, *i.e.*, 4 to 1 against gunpowder? Again, a workman might be seriously injured, maimed for life, or blinded, by burning from gas or by an accident in handling explosives, and such cases could not be ignored in estimating the risks of using the various explosives. And therefore in studying the subject he had taken into account all accidents reported by the inspectors of mines, whether fatal or non-fatal.

The returns of non-fatal accidents from explosions of gas or coal-dust were rather irregular, the causes not being specified in 25 out of 60 of the reports of the inspectors of mines from 1887 to 1891; while from 1892 to 1896, they were not specified in 10 out of 60 of the reports. However, taking all that were recorded, he found that from 1887 to 1891 there were 36 explosions causing 269 deaths and 61 injuries; and from 1892 to 1896, 34 explosions causing 395 deaths and 60 injuries. The number of explosions was less in the second period than in the first, although, with much fuller reports, it might naturally be expected to be greater, and this decrease pointed to the increased safety attained by the more extended use of permitted explosives. For the whole period of 10 years, the number of explosions reported as due to explosives was 70, of which 35 were caused by gunpowder, 5 by dynamite and the other non-permitted high explosives, 24 by tape-fuze or igniters, 4 by unnamed explosives, and only 2—that at Thorncliffe in 1890, and that at Tylorstown in 1896—which even the opponents of safety-explosives could ascribe to those explosives. In both of these cases, tape-fuze was used, and the inspectors of mines stated that it was doubtful whether the explosion was due to the tape-fuze or to the explosive. Even if the members accepted 10 per cent. as the proportion of consumption, the number of accidents from permitted explosives should have been 7 instead of 2, if the two classes of explosives were equally dangerous. It was the fact that not a single gas or coal-dust accident had occurred where a safety-explosive was fired by electricity.

There was a similar irregularity in the reports of the inspectors of mines as to the accidents in handling explosives, as non-fatal accidents were not specified in 18 reports between 1887 and 1891, and in 11 reports from 1892 to 1896. During the first period, the inspectors of mines reported 736 accidents, causing 121 deaths and 738 injuries, and during the second period 848 accidents, causing 105 deaths and 892 injuries. The large number of cases in which the details were imperfect made it difficult to draw a comparison, but it so happened that in six typical districts the reports were very full, and some idea could be

obtained of the relative results of the use of gunpowder and permitted explosives. These districts were :—Newcastle-upon-Tyne, East and West Scotland (in which gunpowder was in almost exclusive use), and Manchester, South Wales, and the Midland district (in which it had been shown that these explosives had largely displaced gunpowder). The following table of the accidents arising from handling explosives had been compiled from the reports of the inspectors of mines :—

THREE DISTRICTS USING GUNPOWDER.

Period.	Average Annual Number of Accidents.	Average Annual Number of Deaths.	Average Annual Number of Persons Injured.
1887-1891	59·6	9·2	59·0
1892-1896	78·7	8·4	83·0
Percentage increase or decrease ...	+32·0	−8·7	+41·0

THREE DISTRICTS USING PERMITTED EXPLOSIVES.

1887-1891	32·8	2·6	38·8
1892-1896	25·2	2·1	27·9
Percentage decrease	23·2	19·2	27·9

The members would see from the preceding table that, in districts where safety-explosives had been substituted for gunpowder and other non-permitted explosives, the annual average of accidents from handling explosives had decreased by nearly one-fourth, whereas in districts where gunpowder remained in the ascendant, the average had increased by nearly one-third.

The total number of accidents due to explosions from all causes, whether by explosion of gas, coal-dust, or in handling explosives was as follows :—

Period.	1887 to 1891.		1892 to 1896.		Total, 1887-1896.	
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Gunpowder	496	64·25	666	75·51	1,162	70·25
Dynamite and other non-permitted high explosives ...	29	3·76	61	6·92	90	5·44
Tape-fuze or igniters	13	1·68	11	1·25	24	1·45
Permitted explosives	4	0·52	48	5·44	52	3·14
Detonators	6	0·77	27	3·06	33	2·00
Not specified	224	29·02	69	7·82	293	17·72
Totals	772	100·00	882	100·00	1,654	100·00

He thought that the figures in the preceding table clearly showed the absurdity of the assertion that the introduction of safety-explosives had caused an increased number of accidents in coal-mines. The real increase in accidents had manifestly been due to the careless use of gunpowder, and that in spite of the promulgation of special preventive rules. It

would be seen that his statistics differed materially from those published by the Gunpowder Trade Association, though they were drawn from the same source, the reports of H.M. inspectors of mines.

Mr. DIXON remarked that the chief objection of Scotch coal-masters to the use of safety-explosives was that they did not do the required work. In his own experience, neither in the blasting of rock, nor brushing, nor in the winning of coal for sale, did high explosives perform the required work so effectively as gunpowder. In brushing, in the majority of shots fired, the stones were so broken that they did not make good buildings or packwalls, and every manager knew the expense of keeping up roads afterwards, when they had not been properly built at first. It had been abundantly proved that high explosives used in mining coal produced more dross.

Mr. J. M. RONALDSON (H.M. Inspector of Mines, Glasgow) said that there was, however, another aspect of the question, and that was in connexion with the handling of explosives. Mr. Hargreaves quoted largely from the reports of H.M. inspectors of mines in England in support of his contention that statistics showed gunpowder to be safer than any other known explosive; but he ought also to have quoted from the reports of the inspectors in Scotland, the more so, seeing that members were specially interested in the safety or otherwise of gunpowder as learnt from experience in Scottish mines. He proposed, therefore, to supply this omission.

The following details refer to accidents which would not have happened if permitted explosives had been used, and which were caused while handling gunpowder, in the West of Scotland mines-inspection district :—

1892.

FATAL.	Deaths.
While forcing compressed powder into shot-hole	2
Sparks from naked light	2
Total	4

NON-FATAL.	No. of Accidents.	Persons Injured.
Sparks from naked light	2	4
Breaking cartridges in shot-hole	1	3
Total	3	7

1895.

FATAL.	Deaths.
While forcing compressed powder into shot-hole	1
Probably a spark from naked light	1
Total	2

NON-FATAL.	No. of Accidents.	Persons Injured.
Sparks from naked light	11	19
Forcing powder into shot-hole	4	5
Total	15	24

1896.

Fatal.	Non-fatal.	No. of Accidents.	Persons Injured.
None.	Sparks from naked lights	15	18

1897 (Part of).

Fatal.	Non-fatal.	No. of Accidents.	Persons Injured.
None.	Sparks from naked lights	5	6
	Fuze lighting loose gunpowder	1	1
	Forcing compressed powder into shot-hole	1	1
	Supposed improper usage	1	2
	Total	8	10

The following accidents also happened during these years :—In 1892, 2 men were injured by an explosion of dynamite while inserting cartridges into a shot-hole. During the present year, a boy was injured by a detonator going off while he was playing with it ; 1 man was killed and 4 others injured by the gunpowder fuze of a carbonite shot igniting fire-damp ; and 2 men were killed while forcing frozen gelignite cartridges into a shot hole.

The members are probably all aware that, in 1894, a new special rule was adopted in Scotland prohibiting a workman from smoking or permitting a naked light to remain on his cap while handling explosives or charging shot-holes. The impression was that, if gunpowder was used with proper precautions, the accidents from sparks from naked lights would be prevented. On referring to the preceding details, it would be seen that, in spite of this regulation, these accidents had largely increased in number. Mr. Hargreaves supported the continued use of gunpowder on account of its safety in handling, but he could not admit this statement as having been proved by facts. If safety-lamps were in general use throughout Scotland, the greatest source of danger from handling explosives, viz., sparks from naked lights, would be removed. But he was not sure that Scottish mine-owners and workmen would be prepared to introduce safety-lamps in order that they might be free to use gunpowder.

Would Mr. Hargreaves tell the members if he was in a position to prove that the samples of gunpowder used by Mr. H. Hall in his experiments were, as he alleged, the very worst of their class? He had not shown from experiments in which high-grade gunpowder was fired in explosive gas and coal-dust that this explosive which he alleged to be as safe as the

permitted explosives was really as safe. Surely before making such a statement, he ought to have satisfied himself that it would stand this test. The tests made by firing charges against sheets of paper smeared with gunpowder paste were interesting in their way, but not conclusive, and from them he was not warranted in coming to the conclusion that a blown-out shot of high-grade gunpowder with sufficient stemming would not ignite coal-dust or fire-damp.

As to the contention that the risks with gunpowder might be minimized, if not entirely obviated, by using sufficient stemming, he would point out that experience had shown that you could not always rely upon workmen stemming their shots properly, and to depend upon this being always done was to run the risk of explosions such as had taken place in the past.

Mr. DIXON asked if Mr. Ronaldson would give them some information as to accidents which had taken place with higher explosives? The one seemed to him to be as dangerous as the other, and with high explosives there would be as much danger as with gunpowder, as new souces of accident would arise.

The PRESIDENT remarked that accidents were as likely to occur when using a permitted explosive as with gunpowder, and it was quite possible that more accidents would ensue from that cause, and from handling them, than with gunpowder.

Mr. RONALDSON stated that only one accident had occurred with gelignite, which was as dangerous as dynamite, if not more so.

Mr. BLYTH (Hamilton) asked why roburite required to be stemmed with a wooden rod?

Mr. ARNOTT (Newton) said that he had used roburite for a large number of years without accident, but when using compressed powder several accidents had occurred, when it was being pushed into the shot-hole.

Mr. FRENCH (Govan) stated that he had used 80 pounds of Mr. Hargreaves' high-grade gunpowder, in charges varying from $\frac{3}{4}$ pound to 2 pounds, and found that they could do more brushing with low-grade gunpowder. Flame had been seen from shots of high-grade gunpowder.

Mr. ORSMAN stated that the temperatures for the nitrate-of-ammonium explosives were not his own, but had been calculated by various chemists, and the actual temperature was probably lower than the theoretical one, this being the usual result in experiments with other

explosives. After all, the difference perhaps was not so much one of temperature, but dependent on the physical condition of the products of explosion. Solid matter in an incandescent state, on account of the long time taken to cool down, must be a more dangerous factor than the presence of gas heated to the same temperature, and high-grade gunpowder did not lessen the temperature or the amount of solid products formed on explosion.

With regard to the relative power of explosives, too much reliance should not be placed upon leaden block experiments, as it had been shown that the size of the hole produced did not represent the total force produced during the whole time of explosion, but depended to a great extent on the speed of detonation. In comparing gunpowder with high explosives it was important that official trials in mines should be made by experts used to handling high explosives, otherwise the tendency was to overcharge, and so blow out a socket instead of producing a shot by which the coal would be brought down in a marketable condition.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE QUEEN'S HOTEL, LEEDS, OCTOBER 2ND, 1897.

MR. GEO. BLAKE WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The PRESIDENT moved a vote of condolence with the family and friends of the late Mr. W. Hoole Chambers, for many years an active and influential member of the Institute.

The vote was carried in silence.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. R. ALTENHEIM, Mechanical Engineer, Foster's Buildings, High Street, Sheffield.

Mr. ALFRED CROWTHER, Mechanical Engineer, West Vale House, Greetland, Halifax.

Mr. RICHARD ANDREW ESCOTT, Mining Engineer, 202, Bishopsgate Street Without, London, E.C.

Mr. CHAS. JAS. MURTON, Colliery Manager, Barrow Collieries, Barnsley,

Mr. FRED. H. WHALLEY, Civil and Mining Engineer, 202, Bishopsgate Street Without, London, E.C.

DISCUSSION ON MR. H. BONSER'S PAPER ON "RECOVERY OF CYANOGEN AND OTHER RESIDUAL PRODUCTS FROM THE WASTE GASES OF COKE-OVENS." *

Mr. L. T. O'SHEA (Sheffield) remarked that Mr. Bonser's paper on the recovery of cyanogen from coke-oven gases introduced a subject of considerable interest, and drew attention to a somewhat new departure in coke-manufacture. For the last 16 or 17 years considerable attention had been given to the question, especially in connexion with gas-manufacture, and of late years British gas-engineers had been occupied

* *Trans. Fed. Inst.*, vol. xiii., page 335.

with investigations on the subject. He was not aware, however, that hitherto the coke-manufacturer had given much attention to the recovery of cyanogen from the gases of the closed oven, and such papers as Mr. Bonser's were valuable in pointing out the possibilities which lay within the reach of distillers of coal. The manufacture of coke in the closed oven is practically the same process as gas-manufacture, and if cyanogen can be profitably recovered in the latter, it should also be possible in the former, where the conditions for the formation of cyanogen are quite as favourable as in gas-manufacture, even if not more so. Dr. Knoblauch, of Cologne, who is a great authority on the subject, states that 2 per cent. of the nitrogen in coal can be obtained as cyanogen: this is equivalent to about 3 lbs. of potassium ferrocyanide per ton of coal, and it has been stated by Mr. Foulis, in the *Gas World*,* that he could obtain 5 lbs. of sodium ferrocyanide per ton of coal. Such results are specially favourable, and it is hardly likely that they represent an average yield, as the formation of cyanogen depends on the quality of the coal and the temperature of distillation. Still, if the yield be taken at from 2 to 2½ lbs. of ferrocyanide per ton of coal, he thought that Mr. Bonser's estimate of the profit, namely, 9d. per ton, was reasonable.

It was difficult to offer much criticism on the process described by Mr. Bonser, as he had given no figures to show how efficiently it works, but he would like to ask him a few questions concerning the results obtained. The success of the Holmes process will depend on (1) the completeness with which the cyanogen is removed from the gases, and (2) the composition of the product formed. The amount of cyanogen in the gases probably does not exceed 0·10 to 0·15 per cent. of the total volume: to remove so small a quantity by a process of washing is a matter of some difficulty, and it would be interesting to know how efficiently the process works in this respect. Sodium ferrocyanide is evidently the ultimate product aimed at in the Holmes process, but it is well known that there is a tendency for sulphocyanides to be formed at the expense of the ferrocyanides, and he would like to ask Mr. Bonser whether any special precautions are taken to prevent the formation of sulphocyanides.

If the results are satisfactory in these respects, the simplicity of the process must commend itself to colliery managers. But the favour with which they regard it will be determined by the commercial success that is likely to attend its adoption, however, at present, the supply of cyanide appears to exceed the demand. When the demand exceeds the supply, there is a chance for the coke-manufacturer to increase the value of his coal by adding 9d. per ton to his receipts. To do this, however, he must

* May 8th, 1897, page 758.

be prepared to take advantage of the opportunity when it arises, and therefore must be quite abreast of his continental competitors, who, in the matter of coke manufacture, are considerably ahead, inasmuch as they realize to the fullest extent the value of recovering bye-products from coke-oven gases. To these products another is now added, and the members must thank Mr. Bonser for his pioneer paper on the subject.

Mr. H. BONSER stated that the cost of the Holmes recovery-apparatus for a gas-works producing 500,000 cubic feet of gas from 50 tons of coal per day was about £1,500—and not as previously stated.*

DISCUSSION ON MESSRS. WALKER AND O'SHEA'S PAPER ON "RECENT PROGRESS IN THE RECOVERY OF BYE-PRODUCTS FROM COKE-OVENS."†

Mr. T. W. H. MITCHELL remarked that all the ovens described in the paper had to be worked without intermission, Sundays included. He wondered whether they would be able to work them in that manner in the present state of the British labour market. He knew that some collieries were working their ovens on Sundays, but those who were not doing it would, he feared, have a hard battle to get it done. Was it absolutely necessary that the working should be continuous? Could not the draught be checked, so as to obviate Sunday work?

DISCUSSION ON MR. G. DUNSTON'S PAPER ON "THE EASTERN EXTENSION OF THE MIDLAND COAL-FIELD, AND THE EXPLORATION AT SOUTHCAR."‡

The PRESIDENT said that the Southcar boring meant an indefinite prolongation of the life of the South Yorkshire coal-field. The depth at which the Barnsley coal-seam had been found at Southcar, 3,500 feet, was a great depth, but, if the seam maintained its valuable character, that depth would not be an insuperable difficulty. The members would look forward to investigations being carried still further eastward, as there was some evidence that coal-seams cropped out in the North Sea, forming the eastern edge of the basin. After passing through the superficial measures, little trouble had been experienced with water in the Southcar boring, so that water was not likely to constitute a serious obstacle to the winning of the coal in that district. It was also proved that there were no very large faults, so that on the whole the problem as

* *Trans. Fed. Inst.*, vol. xiii., page 339. † *Ibid.*, vol. xiii., page 302.
‡ *Ibid.*, vol. xii., page 515; and vol. xiii., page 330.

to the continuance of the coal-field to the east might now be considered to be very satisfactorily demonstrated.

Mr. BONSER said that the bore-hole passed through 6 or 8 feet of gypsum, at a moderate depth. Whatever the depth, considering that Derbyshire gypsum and other mines were worked out, a valuable mine of gypsum was well worth working, and would pay better than the coal.

DISCUSSION ON MESSRS. H. ST. JOHN DURNFORD AND R. HOLIDAY'S PAPER ON "THE USE OF ELECTRICITY AT ACKTON HALL COLLIERY."*

Mr. E. BROWN (St. John's Colliery) said that members seemed now to know the efficiency which could be got out of electrical plant much better than that got out of compressed air. He should like to suggest that someone should isolate a pump driven by compressed air, and let them know the efficiency which could be got out of it, as to which at present no one seemed to be able to speak with authority. Everybody knew that they could by electrical plant get 50 per cent. of efficiency in actual water pumped of what they had in indicated horse-power in the steam cylinder on the surface, but nobody could tell them what they could get out of a compressed-air plant.

DISCUSSION UPON MR. F. COULTAS' PAPER ON "THE GEOLOGY OF DEEPCAR AND ITS SURROUNDING HILLS."†

Mr. COULTAS stated that there were a few corrections to be made in his paper as printed in the *Transactions*. On page 343, the sixth paragraph should read :—"The bed of rocks, which constitutes the well-known Wharncliffe Crags, overlies the beds of shales and binds deposited upon the hard coal-band; and the Loxley Edge rock lies almost directly beneath the White Carr fireclay, particulars of which, and other intervening strata, are shown in Appendix A." In Appendix A, page 345, "Wharncliffe Rock" should read "Loxley Edge Rock." The following corrections should be made in Plate XVIII. of volume xiii. :—The dimensions of the faults lying immediately to the east and west of Deepcar should be deleted (see first paragraph, page 343), and the name of the seam at Townend Common should be "Gannister or Halifax hard coal-seam."

The Woolf safety-lamp, fitted with magnetic-lock and self-igniting apparatus, and the pneumatophore‡ (breathing apparatus) were exhibited.

* *Trans. Fed. Inst.*, vol. xiii., page 232. † *Ibid.*, vol. xiii., page 341.
‡ *Ibid.*, vol. xii., page 693.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, AUGUST 7TH, 1897.

MR. THOMAS DOUGLAS, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on July 24th and that day.

The SECRETARY also reported the proceedings of the Council of The Federated Institution of Mining Engineers.

ELECTION OF OFFICERS.

The CHAIRMAN appointed Messrs. W. C. Cockburn, J. Cook, R. Laverick, and T. Lowden as scrutineers of the balloting-papers for the election of officers for the year 1897-98. The scrutineers afterwards reported the result of the ballot as follows:—

PRESIDENT.

MR. GEORGE MAY.

VICE-PRESIDENTS.

Mr. W. ARMSTRONG.	Sir W. T. LEWIS.
Mr. T. W. BENSON.	Mr. R. ROBINSON.
Mr. C. BERKLEY.	Mr. W. O. WOOD.

COUNCIL.

Mr. HENRY AYTON.	Mr. W. LOGAN.
Mr. R. DONALD BAIN.	Mr. HENRY LOUIS.
Mr. J. R. CRONE.	Mr. J. H. MERIVALE.
Mr. T. E. FORSTER.	Mr. H. PALMER.
Mr. T. Y. GREENER.	Mr. A. M. POTTER.
Mr. T. E. JOBLING.	Mr. H. RICHARDSON.
Mr. A. C. KAYLL.	Mr. F. R. SIMPSON.
Mr. H. LAWRENCE.	Mr. JOHN SIMPSON.
Mr. C. C. LEACH.	Mr. R. L. WEEKS.

The CHAIRMAN proposed a vote of thanks to the Vice-Presidents, Councillors, Treasurer, and Secretary for their services during the past year, which was agreed to.

The CHAIRMAN moved, and Mr. M. WALTON BROWN seconded, that a vote of thanks be accorded to the scrutineers for their services, which was agreed to.

The CHAIRMAN referred to the honour of a baronetcy which had been conferred upon one of their members and a Past-President, Sir Lindsay Wood. Those who had been associated with that gentlemen for a number of years would feel that this honour was a recognition of services so well rendered to the coal trade, and with great pleasure he proposed that the Secretary be desired to convey to Sir Lindsay Wood the congratulations of the members on the honour which had been conferred upon him.

Mr. J. B. SIMPSON, in seconding the proposal, endorsed most heartily the remarks of the Chairman. The members admired Sir Lindsay Wood, and were under great obligations to him, even if it were only for the position which he had taken up in connexion with this Institute. He was one of the oldest members, and had always taken a lively interest in its welfare, and had read some valuable papers, which had been printed in the *Transactions*.

The vote of congratulation was adopted.

The SECRETARY read the Annual Report of the Council as follows:—

ANNUAL REPORT OF THE COUNCIL, 1896-97.

The following table shows the numbers of members of various classes during a few recent years:—

	August 1st.		
	1895.	1896.	1897.
Honorary Members...	26	23	29
Members	717	767	829
Associate Members	67	78	98
Associates	67	83	91
Students	36	46	45
Subscribers	23	23	23
Totals	936	1,020	1,115

The continued increase of the membership is a matter of congratulation, and the Council trust that the members will, at all times, endeavour to extend the membership. The formation of the class of Associates, consisting of persons occupying subordinate positions in mining, has proved very successful, and, together with the Students, has materially increased the roll of members.

The members have to regret the death of Mr. William Armstrong, one of the original members of the Institute and a Vice-President, who had been actively connected with the Institute from its commencement in 1852.

The thanks of the members have been accorded to Messrs. W. C. and G. R. Cockburn for presenting an oil-painting of the late Mr. Nicholas Wood, the first President of the Institute.

The following alterations of Bye-laws 13 and 17 were adopted at a Special General Meeting of the members, and have been approved by the Secretary of State for the Home Department :—

13.—The *Transactions* of the Institute shall not be forwarded to those whose subscriptions are in arrear on the first of November in each year.

17.—Any Member, Associate Member, Associate or Student may, at any time, compound for all future subscriptions by a payment in accordance with the following scale :—

Under	30	years of age,	the sum of	£31
Over	30	,,	,,	27
,,	40	,,	,,	24
,,	50	,,	,,	21
,,	60	,,	,,	17

or on such other conditions as the Council may, in writing, accept. Every person so compounding shall be a Member, Associate Member, Associate or Student for life, as the case may be. Any Associate Member, Associate or Student so compounding who may afterwards be qualified to become a Member, may do so, by election in the manner described in Bye-law 8. All compositions shall be deemed capital money of the Institute.

A Departmental Committee has been appointed by the Secretary of State for the Home Department to test explosives for the purposes of the Coal Mines Regulation Act, 1896, and a government testing-station has been erected near Woolwich. It is a matter for regret that the request made by the Institute has not been acceded to, that the extensive explosives testing-plant erected at Hebburn should be maintained and used as a testing-station under government patronage.

The meetings of Students have been continued, and four papers have been printed in the *Transactions*.

It is anticipated that a meeting of members of the Western Australian branch will shortly be held in Perth for the reading and

discussion of papers; and the Council trust that Indian and Colonial members will promote the formation of similar localized branches.

The Report of the Committee on Mechanical Ventilators is completed, and will be issued to the members during the course of the next few months.

The sixth volume of the *Sinkings and Borings* (U to Z) will shortly be completed, and members are requested to send copies of any unpublished sections of strata in Northumberland or Durham to the Secretary, with the view of their being published in a supplementary volume.

A General Index to Volumes I. to XXXVIII. of the *Transactions* of the Institute is in preparation, and the Council trust that it will be received with approval by the Members.

The additions to the Library by donations, exchanges, purchase, etc., have been:—

Bound volumes	275	
Pamphlets, reports, etc.	243	
A total of	518	titles.

The Library now contains 7,453 volumes and 1,504 unbound pamphlets, etc. The card catalogue is completed, and the books are now readily accessible to the members. The Library (including the books and numerous technical newspapers) is open from 10 a.m. to 5 p.m., and members residing at a distance may make use of the books, on payment of carriage, by application to the Secretary. Some of the files of publications have been rendered incomplete by the neglect of members to return books to the Library, and it is urgently requested that they search for and return the missing volumes.

By mutual arrangement with the Literary and Philosophical Society of Newcastle-upon-Tyne, the doorway between the adjacent libraries is opened daily, and the members of either society are allowed (on the production of a member's pass) to refer to the books in the library of the other society.

The Library would be rendered more valuable if members would present volumes, etc., which they can spare from their own libraries, and they would also render valuable service to the profession by bequeathing books, reports, plans, etc., to the Library, where they would be preserved, be available for reference, and perpetuate the memory of the donor. The Watson collection of mining plans, reports, etc., has proved most valuable for purposes of reference.

The prices of the *Transactions* and other publications have been con-

siderably reduced, and members are recommended to complete their sets before the stock is exhausted (some of the volumes being already sold out).

Mr. W. Hamilton Merritt has been appointed to represent the Institute at the Conference of Corresponding Societies of the British Association for the Advancement of Science, to be held in Toronto, Canada, in August, 1897. Mr. John Daglish acts on behalf of the Institute as a governor of the Durham College of Science, Newcastle-upon-Tyne. Mr. W. Cochrane is the Institute representative on the Science and Art Committee, and Mr. J. L. Hedley on the Scholarships Committee of the Northumberland County Council.

The Federated Institution of Mining Engineers has now completed its eighth year, during which general meetings have been held in South Wales on September 15th, 16th, and 17th, 1896; in Lancashire on February 17th, 18th, and 19th, 1897; and in London on June 3rd, 4th, and 5th, 1897. An excursion meeting was held in Belgium, on June 7th, 8th, 9th, and 10th, when the members visited some of the principal collieries and works. A meeting of students and junior members was held in Yorkshire on August 5th, 6th, and 7th, 1896. The success that has attended the working of The Federated Institution of Mining Engineers would be more completely assured, if it embraced all the societies interested in mining, metallurgy, and their allied industries. The Council therefore urge members, who may be interested in other societies, to use their influence in favour of federation. Apart from other advantages, each member of one of the six federated societies receives, yearly, two volumes of *Transactions*, comprising some 70 or 80 papers and upwards of 150 notes of papers on subjects of general and special interest.

The late President's (Mr. Thomas Douglas) students' prize was awarded to Messrs. W. R. Bell and E. McGowan for their paper on "Haulage at Wearmouth Colliery."

Prizes of books have been awarded to the writers of the following papers, communicated to the members during the year 1895-96:—

"Coal-cutting by Machinery." By Mr. Wm. Blakemore.
"The Resistances of Air-currents in Mines." By Mr. T. L. Elwen.
"A Compound Winding-engine." By Mr. William Galloway.
"The Quicksilver Mines and Reduction-works at Huitzuco, Guerrerro, Mexico." By Mr. Edward Halse.
"The Whitehaven Sandstone Series." By Mr. J. D. Kendall.
"Notes on the Geological Features of the Coast of North Wales from Liverpool to Menai Bridge." By Mr. C. E. de Rance.
"The Mode of Obtaining a True North Line." By Mr. A. L. Steavenson.
"Safety Explosives." By Bergassessor Winkhaus.

The papers communicated to the members during the year have been as follows:—

"Shaw Gas-tester." By Dr. P. P. Bedson.
"Notes upon Gold-mining in Burma." By Mr. A. H. Bromly.
"Eccentric Haulage-clip." By Mr. John Brown.*
"Notes on the Venterskroom Gold-fields, South African Republic." By Mr. H. B. Bunkell.
"The Gold-fields of the Hauraki Peninsula, New Zealand." By the Rev. Joseph Campbell.
"Cornish Methods of Mine-timbering." By Mr. G. P. Chaplin.*
"The Mineral Resources of the Colony of Queensland." By Mr. William Fryar.
"Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant." By Mr. W. T. Hallimond.
"The Coal-industry of the South-eastern States of North America." By Mr. Jeremiah Head.
"A Spring-coupling for Winding or Hauling-ropes." By Mr. H. W. Hollis.
"Notes upon Foreign Mining Laws and Adequate Areas for Mining Concessions." By Mr. H. D. Hoskold.
"Honigmann System of Boring and Sinking Shafts." By Mr. Th. Lichtenberger.
"Note on the Tellurium Mineral of Choukpazat, Burma." By Prof. Henry Louis.
"Notes on Coal-mining." By Messrs. Algernon Noble and Norman Nisbet.*
"Economical Combustion of Coal for Steam-raising Purposes." By Mr. T. E. Parrington.*
"The Education of Metallurgists." By Mr. Saville Shaw.
"Notes on the Sinking of Two Shafts at Claravale Colliery, near Wylam-upon-Tyne." By Mr. Frank R. Simpson.
"Further Experiments with Explosives." By Bergassessor Winkhaus.
"The Danger of Employing Safety-fuzes for Blasting in Fiery Mines." By Bergassessor Winkhaus.

In conclusion, the Council urge the members to use their best endeavours to increase the membership, as the continued success of the Institute will depend upon its ability to pay the expenses of committees appointed to carry out investigations on questions of interest to the professions of mining or mechanical engineering, and to meet the considerable expenses incurred by the connexion of the Institute with The Federated Institution of Mining Engineers.

Mr. J. B. SIMPSON, in moving the adoption of the report, said that it was satisfactory to find that during the past two years the membership had largely increased, and that they had now a greater number of members than at any time since the formation of the Institute.

* Student's paper.

Another interesting feature of the report referred to the facilities afforded to the members by their valuable library, which was one of the best mining libraries in the world.

Mr. W. S. HARRIS seconded the resolution, which was unanimously adopted.

The TREASURER read the Report of the Finance Committee as follows:—

REPORT OF THE FINANCE COMMITTEE.

The total income for the year amounted to £2,423 2s. 4d.; deducting from this the sum of £155, compositions in lieu of annual subscriptions; £49 7s. 0d., subscriptions paid in advance; and £16 0s. 4d. received from The Midland Institute of Mining, Civil, and Mechanical Engineers as their moiety of the expenses of the Fan Ventilation Committee; the sum of £2,202 15s. 0d. remains as the ordinary income of the year, compared with £2,154 15s. 9d. for the previous year—an increase of £47 19s. 3d.

In accordance with the decision of the Council, the names of several members whose subscriptions were in arrear, have been struck out of the list of members. The amounts written off in consequence are:—For current year, £38 17s. 0d.; and arrears, £32 11s. 0d. The amount of subscriptions now in arrear, in excess of one year, is £53 11s. 0d.

The total expenditure amounted to £2,056 2s. 11d., a decrease of £179 9s. 1d. The principal items accounting for this decrease are the closing of the expenditure of the Explosives Committee, and a decrease in the amount paid for printing and stationery.

The contributions to The Federated Institution of Mining Engineers, amounted to £999 18s. 6d., an increase of £106 4s. 8d., due to the increased number of members.

During the year the sum of £200 was placed on deposit account with the bankers, and it is proposed that a further sum of £250 be similarly deposited pending the selection of a suitable investment.

The CHAIRMAN moved the adoption of the report, and this being seconded by Mr. J. B. SIMPSON, was unanimously adopted.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND FOR THE YEAR ENDING

	£ s. d.	£ s. d.
July 28th, 1896.		
To Balance at Bankers	575 17 8	
„ „ in Treasurer's hands	83 7 1	
„ Outstanding Amounts due for Authors' Excerpts ...	4 13 9	
		663 18 6
July 31st, 1897.		
To Dividend of 7½ per cent. on 146 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd., for year ending June, 1897	219 0 0	
„ Interest on Mortgage of £1,400 with Institute and Coal Trade Chambers Company, Ltd.	49 0 0	
		268 0 0
„ Midland Institute of Mining, Civil, and Mechanical Engineers, Fan Committee Expenses		16 0 4
„ Sales of Publications		14 6 0
To SUBSCRIPTIONS FOR 1896-97 AS FOLLOWS:—		
608 Members ... ... @ £2 2s.	1,276 16 0	
55 Associate Members ... ... @ £2 2s.	115 10 0	
70 Associates ... ... @ £1 1s.	73 10 0	
31 Students ... ... @ £1 1s.	32 11 0	
81 New Members ... ... @ £2 2s.	170 2 0	
36 New Associate Members ... ... @ £2 2s.	75 12 0	
9 New Associates ... ... @ £1 1s.	9 9 0	
8 New Students ... ... @ £1 1s.	8 8 0	
	1,761 18 0	
To SUBSCRIBING FIRMS, VIZ.:— £ s. d.		
11 @ £2 2s.	23 2 0	
6 @ £4 4s.	25 4 0	
2 @ £6 6s.	12 12 0	
3 @ £10 10s.	31 10 0	
	92 8 0	
To Subscriptions in Suspense...	12 12 0	
	1,866 18 0	
To 7 Members' Life Compositions	155 0 0	
	2,021 18 0	
Less—Subscriptions for current year paid in advance at the end of last year...	126 0 0	
	1,895 18 0	
Add Arrears received	179 11 0	
	2,075 9 0	
Add Subscriptions paid in advance during current year	49 7 0	
		2,124 16 0
		£3,087 0 10

INSTITUTE OF MINING AND MECHANICAL ENGINEERS Cr.

JULY 31ST, 1897.

July 31st, 1897.	£	s.	d.	£	s.	d.
By Printing and Stationery				195	1	4
„ Books for Library	45	17	11			
„ Prizes for Papers	16	16	0			
„ Incidental Expenses	52	13	10			
„ Postages	62	0	0			
„ Sundry Accounts	8	18	7			
„ Travelling Expenses	0	3	0			
„ Salaries	150	0	0			
„ Clerks' Wages	197	12	4			
„ Reporter's Salary	12	12	0			
„ Rent	99	15	0			
„ Rates and Taxes	18	15	5			
„ Insurance	9	7	4			
„ Furnishing and Repairs	73	4	11			
„ Coals, Gas, Electric Light, and Water	45	13	8			
„ Translations of Papers	4	15	0			
„ Library Card Catalogue	26	13	8			
„ Expenses of Meetings	25	10	2			
				850	8	10
By Explosives Committee	1	14	3			
„ Fan Committee	2	0	0			
„ British Association Meeting—Delegate's Expenses ...	7	0	0			
				10	14	3
By The Federated Institution of Mining Engineers—						
Subscriptions	1,017	10	5			
Less—Amounts paid by Authors for Excerpts ...	17	11	11			
				999	18	6
				2,056	2	11
By Investments—						
Lambton & Co. Deposit Account				200	0	0
				2,256	2	11
By Balance at Bankers	725	10	6			
„ „ in Treasurer's hands	100	0	0			
Outstanding Amounts due for Authors' Excerpts ...	5	7	5			
				830	17	11
				£3,087	0	10

I have examined the above account with the books and vouchers relating thereto, and certify that, in my opinion, it is correct.

JOHN G. BENSON,
CHARTERED ACCOUNTANT.

Newcastle-upon-Tyne,
August 6th, 1897.

DR. THE TREASURER IN ACCOUNT

			£	s.	d.	£	s.	d.
To 767 Members, 34 of whom are Life Members.								
733	733	@ £2 2s.				1,539	6	0
To 78 Associate Members, 6 of whom are Life Members.								
72	72	@ £2 2s.				151	4	0
To 83 Associates		@ £1 1s.				87	3	0
To 46 Students		@ £1 1s.				48	6	0
To 23 Subscribing Collieries						96	12	0
To 7 New Members, paid Life Composition						155	0	0
To 81 New Members		@ £2 2s.				170	2	0
To 36 New Associate Members		@ £2 2s.				75	12	0
To 9 New Associates		@ £1 1s.				9	9	0
To 8 New Students		@ £1 1s.				8	8	0
To Subscriptions in Suspense						12	12	0
						2,353	14	0
To Arrears, as per Balance Sheet 1895-96			253	1	0			
Less—Amount transferred from Suspense			2	2	0			
			250	19	0			
Add—Arrears considered irrecoverable, but since received			14	14	0			
			265	13	0			
Less—Struck off as irrecoverable—Arrears		£32 11 0						
" " "	Current year	38 17 0						
			71	8	0			
						194	5	0
						2,547	19	0
To Subscriptions Paid in Advance						49	7	0
						£2,597	6	0

WITH SUBSCRIPTIONS, 1896-97. CR.

		PAID. £ s. d.	UNPAID. £ s. d.
By 608 Members, paid	@ £2 2s.	1,276 16 0	.....
By 118 „ unpaid	@ £2 2s.	.....	247 16 0
By 7 „ dead	@ £2 2s.	.....	14 14 0
733			
By 55 Associate Members, paid	@ £2 2s.	115 10 0	.....
By 16 „ „ unpaid	@ £2 2s.	.....	33 12 0
By 1 „ „ dead	@ £2 2s.	.....	2 2 0
72			
By 70 Associates, paid	@ £1 1s.	73 10 0	.....
By 12 „ unpaid	@ £1 1s.	.....	12 12 0
By 1 „ paid as Member		.....	1 1 0
83			
By 31 Students, paid	@ £1 1s.	32 11 0	.....
By 14 „ unpaid	@ £1 1s.	.....	14 14 0
By 1 „ dead	@ £1 1s.	... ..	1 1 0
46			
By 22 Subscribing Collieries, paid		92 8 0	.....
By 1 „ „ unpaid		.....	4 4 0
23			
By 7 New Members, paid Life Composition		155 0 0	.....
By 81 New Members, paid	@ £2 2s.	170 2 0	.....
By 36 New Associate Members, paid ...	@ £2 2s.	75 12 0	.....
By 9 New Associates, paid	@ £1 1s.	9 9 0	.....
By 8 New Students, paid	@ £1 1s.	8 8 0	.....
By Subscriptions in Suspense		12 12 0	.....
		2,021 18 0	331 16 0
Less—Struck off as irrecoverable		.....	38 17 0
			292 19 0
By Arrears		179 11 0	53 11 0
By Subscriptions paid in advance		49 7 0	.....
		2,250 16 0	346 10 0
			2,250 16 0
			£2,597 6 0

General Statement, July 31st, 1897.

Liabilities.	£ s. d.	£ s. d.
Subscriptions paid in Advance during the year	49 7 0	
„ carried over from previous year	2 2 0	
		51 9 0
Capital		8,769 13 1
		£8,821 2 1

I have examined the above account with the books and vouchers relating thereto, and certify that, in my opinion, it is correct. The Share Certificates and Mortgage Bonds have been produced to me.

JOHN G. BENSON,
Chartered Accountant.

Newcastle-upon-Tyne,
August 6th, 1897.

Assets.	£ s. d.	£ s. d.
Balance of Account at Bankers	725 10 6	
„ in Treasurer's hands	100 0 0	
Outstanding amounts due for Authors' Excerpts	5 7 5	
		830 17 11
Proportion of Fan Committee Expenses— South Wales Institute of Engineers		34 6 8
Arrears of Subscriptions		346 10 0
146 Shares in the Institute and Coal Trade Chambers Co., Ltd. (at cost)	3,130 0 0	
Investment with the Institute and Coal Trade Chambers Co., Ltd. (Mortgage)	1,400 0 0	
		4,530 0 0
(Of the above amount, £350 is due to Life Subscriptions Account, leaving £210 12s. not invested.)		
Deposit with Lambton & Co.		200 0 0
Value of Transactions and other Publications, as per Stock Account		679 7 6
Office Furniture and Fittings	450 0 0	
Books and Maps in Library	1,750 0 0	
		2,200 0 0
		£8,821 2 1

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

The CHAIRMAN moved, and Mr. JOHN SIMPSON seconded, a resolution that the following gentlemen be elected as the representatives of the Institute on the Council of The Federated Institution of Mining Engineers:—

Mr. HENRY ARMSTRONG.
Mr. WM. ARMSTRONG.
Mr. HENRY AYTON.
Mr. R. DONALD BAIN.
Mr. JOHN BATEY.
Sir LOWTHIAN BELL, Bart.
Mr. T. FORSTER BROWN.
Mr. W. COCHRANE.
Mr. E. W. CRONE.
Mr. J. DAGLISH.
Mr. T. DOUGLAS.
Mr. G. B. FORSTER.
Mr. T. E. FORSTER.
Mr. W. GALLOWAY.
Mr. J. GERRARD.
Mr. W. F. HALL.
Mr. J. HEAD.
Mr. J. L. HEDLEY.
Mr. A. C. KAYLL.
Mr. HENRY LOUIS.
Mr. JAMES MCMURTRIE.
Mr. G. MAY.
Mr. J. MORISON.
Mr. H. PALMER.
Mr. M. W. PARRINGTON.
Mr. F. R. SIMPSON.
Mr. J. B. SIMPSON.
Mr. A. L. STEAVENSON.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. WILLIAM ABRAHAMS, Government Inspector of Mines (Victoria), Bendigo, Victoria, Australia.

Mr. JAMES MAYNE CRAZE, Mining Engineer, Coolgardie, Western Australia.

Mr. HOWARD HARRIS, Mechanical and Mining Engineer, Tyne Valley Colliery, Springs, Transvaal.

Mr. GEORGE FREDERICK LABRAM, Chief Engineer, De Beers Consolidated Mines, Limited, Kimberley, South Africa.

Mr. THOMAS HAIGHT LEGGETT, Consulting Mining Engineer, P.O. Box 485, Johannesburg, Transvaal.

Mr. JOHN MORGAN, Mine Manager, Norseman Gold-mining Company, Limited, Norseman, Western Australia.

Mr. WILLIAM PILE, Consulting and Mechanical Engineer, P.O. Box 1,093, Johannesburg, Transvaal.

Mr. ROBERT THOMAS REES, Mining Engineer, Glandare, Aberdare.

Mr. ANDREW ROBERTSON, Consulting Mining Engineer, 49, Mining Exchange, Ballarat, Victoria.

Mr. ARTHUR THOMAS, Mining Engineer, Mina El Carmen, El Oro, Tultenango, Mexico.

ASSOCIATE MEMBERS—

Mr. ALBERT MONTAGUE ARMSTRONG, 3 and 4, Crooked Lane, King William Street, London, E.C.

Mr. A. CROSBY, Kroomfontein Coal Company, Limited, Brugspruit, District Middelburg, Transvaal.

Mr. C. GORDON RICHARDSON, c/o Messrs. Geo. Wm. Ballou & Company, 10, Wall Street, New York, U.S.A.

Mr. L. W. TATUM, c/o Messrs. Dwight, Furness & Company, San Luis de la Paz, State of Guanajuato, Mexico.

Mr. WILLIAM W. VAN NESS, Buluwayo, Matabeleland, South Africa.

ASSOCIATE—

Mr. FOSTER STEPHENSON, Coal-hewer, Double Row, Seaton Delaval, Northumberland.

STUDENT—

Mr. FRANK DOUGLAS MURRAY, Mining Student, 29, Albemarle Street, London; and Wardley Hall, near Newcastle-upon-Tyne.

The SECRETARY read the following paper, by Mr. Frank Reed, Inspector of Mines, on the "Hydrothermal Gold-deposits at Peak Hill, Western Australia":—

HYDROTHERMAL GOLD-DEPOSITS AT PEAK HILL, WESTERN AUSTRALIA.

By FRANK REED, Inspector of Mines, Western Australia.

The Peak Hill mines are situated between the Murchison and Gascoyne rivers, about 90 miles due north-north-east of Nannine, in latitude 25° 38′ S., and are approached by a good coach-road from Nannine *via* Mount Vranizan, Abbotts, and Mount Fraser.

Geological History.—An inspection of the geological map (Fig. 1, Plate II.) will indicate the geological formations which occur on the Peak Hill gold-field.

On the road to Peak Hill, the outcrops consist of Archæan rocks, gneiss, and granite, the basis or skeleton of the whole colony; diorite in massive or banded form (dioritic schists) the country-rock of West Australian gold; and the writer frequently found the beds of rivers and creeks lined with Neogene ferruginous sandstone.

The mines at Peak Hill are situated on a flat, in area about 160 acres (Fig. 2, Plate II.), at the foot of a small diorite hill, from which the place takes its name.

The middle of this flat is covered by a bed of auriferous cement, frequently containing small angular quartz-fragments in a ferruginous matrix, with horizontal laminations; this cement contains gold both in a disseminated form as well as in nuggets or "slugs," the largest of these yet discovered weighing about 90 ounces. The cement covers an area of about 20 acres, and has an average thickness of 4 feet.

In this cement-bed a number of large holes occur of inverted bell-shape, evidently extinct thermal craters: these vary in size up to 20 feet in diameter and 15 feet in depth; the holes are now mostly filled with loose subaërial or alluvial deposits (Fig. 3, Plate II.). The craters pass through the cement-beds into the strata beneath, consisting of decomposed and altered dioritic schists, in places containing auriferous quartz-veins, which veins pass upwards through the cement-beds and outcrop at the surface.

In the vicinity of these quartz-veins or leaders, the dioritic schists underlying the cement-beds have become entirely altered by hydrothermal or fumarole action, evidently a sequence of volcanic activity, during which the dioritic country-rock has become fractured, and deep-seated hydrothermal waters existing at high-pressure, and charged with alkaline, calcic, or magnesic carbonates, and holding gold in solution, have used the fractured parts of the rocks as a passage along the lines of least resistance to the surface.

The lines of fracture which have served as vents or conduits are now cemented and filled with hæmatite-stained quartz, and are often phenomenally rich in gold. The quartz-veins taken separately are not regular in course or inclination, but taken as a whole, several veins often occurring in close proximity, they appear much more regular and the angle of inclination appears to increase as depth is attained.

The quartz-veins frequently terminate at the extinct craters previously referred to, showing that the craters have formed the orifices or outlets for the thermal solutions.

In the immediate locality of the quartz-veins, the dioritic schist has become entirely kaolinized by the hydrothermal and fumarole action, and the solutions have penetrated into the kaolin and precipitated gold in the same, that nearest the vein receiving the greater proportion of gold.

Immediately adjacent to the veins or vents, the kaolinized rock is white in colour, and this changes to yellow and afterwards to a bluish grey before eventually assuming its dioritic schistose character at that point where the influence of the thermal solutions and fumarole effects have not penetrated.

State of Mining.—Although gold was first discovered on the Peak Hill gold-field in 1892, it is only within the past 2 years that other than surface-mining has been conducted.

The area at present being worked at Peak Hill "patch" (as the hydrothermal auriferous deposits previously referred to are termed locally) is about 130 acres, comprised in 18 leases.

The workings at the date of the writer's last visit of inspection on March 14th, 1897, had not in any instance exceeded 90 feet in depth, and as the water-level is not reached until a depth of 230 feet, the owners of the leases have plenty of "backs" to work before pumping operations will become necessary.

Owing to the remarkable richness of the ground, the owners, who generally consist of three or four working "mates," mine the ground

themselves, working out only the richest of the formation of quartz-veins and kaolin, and ore which would pay any company to work is left behind. The results of their crushings of the mined ore are phenomenal, as will be seen upon inspection of the battery returns.

Battery Returns.—The following table of battery returns includes every crushing which has taken place up to March 14th, 1897, at the Peak Hill public battery, the only crushing-plant on this gold-field.

The material is only treated by battery-amalgamation, and owing to the quantity of slimes produced from the kaolin, a considerable amount of gold, varying between 1 and 3 ounces per ton of ore crushed, is lost in the tailings. Owing to the absence of sulphides, the Peak Hill ore is eminently adapted for the cyanide process of gold-extraction, which would save the above-named loss in the tailings.

RETURN OF ORE CRUSHED FROM ALL MINES IN THE PEAK HILL GOLD-FIELD TO MARCH 14TH, 1897.

Name of Mine.	Area of Lease.	Quantity of Ore Crushed.	Yield of Smelted Gold.	Average Yield of Gold per Ton.	Description of Ore Crushed.
	Acres.	Tons	Ozs. Dwts.	Ounces.	
No. 1 North ...	6	128	497 8	3·89	Quartz & kaolin.
Atlantic ...	6	121	485 9	4·09	,, ,,
Bobby Dazzler...	6	106	333 0	3·14	,, ,,
North Star ...	6	178½	707 0	3·96	,, ,,
Peak Hill Reef	9	331	2,621 16	7·92	,, ,,
Daisy Bell ...	—	133	1,788 17	13 45	,, ,,
Golden Chimes	—	195	1,402 9	7·14	,, ,,
Commercial ...	6	70	551 0	7·87	,, ,,
Evening Star ...	6	61¼	66 0	1·04	,, ,,
Reward Claim...	—	725	885 9	1·22	Cement.
,, ,, ...	-	not known	(3,766 0)	—	—
Totals ...	—	2,048¾	9,348 8	4·56	—

NOTE.—The value of the smelted gold from Peak Hill mine is always above £4 per ounce, and has reached £4 1s. 6d.

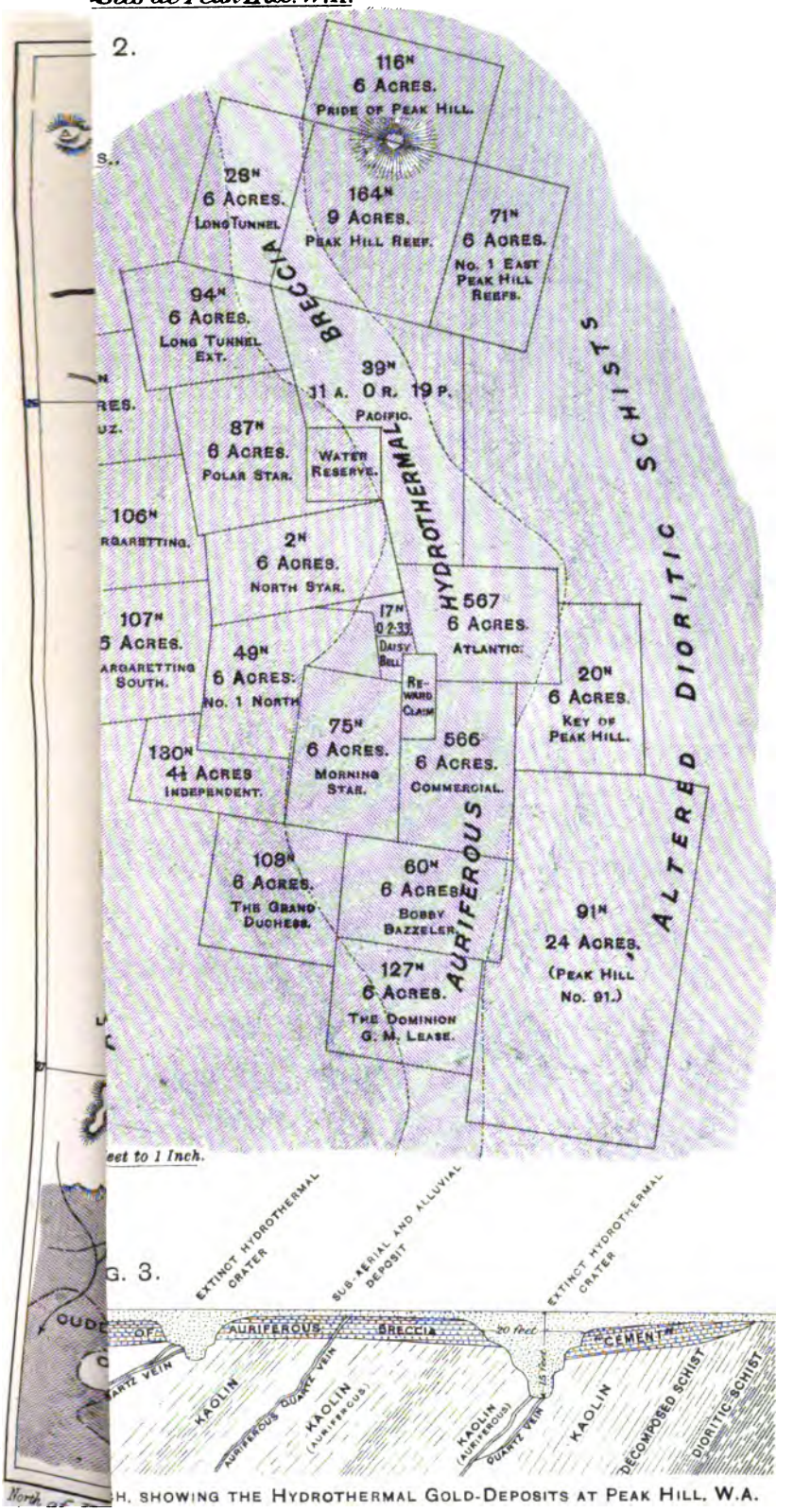
Although mining operations at Peak Hill have not exceeded a depth of 90 feet, the writer is of opinion that owing to the deep-seated origin of the auriferous thermal solutions and the fissures or vents which have once served as their conduits, it is reasonable to conclude that the decomposing influence of the former has acted in a similar manner at lower levels on the dioritic schists, and that at least as much gold has been precipitated in the kaolinized rocks and the fissures in the lower ground as is now found comparatively near the surface. The writer, consequently, believes that the auriferous formation will exist to a considerable depth and that

the mass of auriferous quartz-veins will tend to concentrate and assume a more lode-like form with a greater degree of inclination at lower levels, which tendency the writer has already observed in the lower workings of two of the mines.

In connexion with the dioritic schist-rock, which is a characteristic of the Western Australian gold-fields, the writer may state that this formation originally consisted of massive diorite or diabase, but by tangential dynamic pressure it has assumed a schistose form. These dioritic schists occur as breaks in the Archæan gneiss and granite, and form the country-rock of the Western Australian gold-fields.

The CHAIRMAN moved a vote of thanks to Mr. Reed for his interesting paper, and the motion was cordially approved.

The SECRETARY read the following paper, by Mr. Wm. B. Phillips, on "The Gold Regions of Alabama, U.S.A.":—



H, SHOWING THE HYDROTHERMAL GOLD-DEPOSITS AT PEAK HILL, W.A.

THE GOLD REGIONS OF ALABAMA, U.S.A.

By WM. B. PHILLIPS.

Since the admission of Alabama into the Union, as a state, in 1819, there has been more or less interest exhibited in the possibility of working the gold-deposits profitably. In the early days, from 1830 to 1850, a very considerable amount of work was done, the culminating period being between 1845 and 1855.

Immediately prior to the California gold-fever, in 1849, there were some 5,000 men employed in the counties of Chilton, Coosa, Tallapoosa, Clay, and Cleburne, the town of Arbacoochee, in Cleburne county, alone having a tributary population of 2,000 to 3,000. Those were the days of the crudest sort of stamp-mills, of sluice-boxes, long-toms, and cradles. It is more than probable that the stamp-mill, as applied to gold-ores, had its origin in the northern part of Georgia, near Dahlonega, a district some 200 miles north-east, as the crow flies, from the Alabama gold-regions. It was not a Californian invention, although the irony of history has long since obscured the fame of the Georgian inventor.

The ores treated were the placer-gravels and the upper portion of the quartz-reefs, the one for nugget-gold, the other for the gold equally free but in a finer state of division. No large nuggets have ever been found in the state of Alabama, the largest being valued at £50 ($240), and coming from the Arbacoochee placer in Cleburne county, now practically exhausted. The workings on the quartz-reefs seldom exceeded 40 feet in depth, and were discontinued when the harder rock was struck at water-level, and when sulphide ores began to appear.

According to Dr. Eugene A. Smith, state geologist,* the total area of the crystalline rocks in Alabama is 4,425 square miles, but in a report to the Geological Survey, in 1891-92, the writer estimated the productive area at about 3,500 square miles, and it is likely, so far as concerns the profitable working of the gold-ores, that this estimate will have to be diminished by one-half. The area covered by the crystalline rocks, whether of pre-Silurian or Silurian age, lies in the eastern part of the state, south of a line drawn from Atlanta, Georgia, to Birmingham, and

* *Agricultural Report* for 1881-2.

east of a line drawn from Birmingham to Columbus, Georgia. Roughly speaking, it forms a triangle of 90 miles to each side. Within this area, occur granites, gneisses, crystalline schists, and marbles. It forms in reality the south-eastern prolongation of the Appalachian Mountains, which extend, almost without a break, along the Atlantic slope of the United States, from the northern boundary of New Hampshire to the middle of Alabama, a distance of 1,500 miles. The highest peak along this range is Mitchell's High Peak, in the western part of North Carolina, which rises to an elevation of 6,688 feet. From that point towards the south-east, the peaks gradually decrease in height until in Alabama the height is but 2,400 feet in Mount Chewacla, Clay county.

Disregarding the placers, which really do not cut much of a figure, the gold-ores of Alabama are of two kinds, quartz-reefs and decomposed schist, or gneiss, the so-called "saprolite" of Dr. Becker (a term applied to decomposed rock *in situ*).

The quartz-reefs do not differ essentially from such occurrences elsewhere along the Atlantic slope, in Virginia, North and South Carolina, and Georgia. In Alabama, the prevailing strike is about 25 degrees north of east, with a south-easterly dip, varying from 25 to 40 degrees. They are held in the ordinary country-rock, be it slate or schist, carry free-gold in the upper levels, with little or no sulphide ores, and pass gradually into sulphide ores below water-level. Practically all of the gold in the upper levels is free, but when the undecomposed ore is struck, the ratio of the free-gold to that held in the sulphide ores is about as 1 to 3, *i.e.*, a sulphide ore carrying 37s. 6d. ($9) per ton will have about 12s. 6d. ($3) per ton of free-gold. This, however, is true only in a general way, and cannot be asserted as to all sulphide ores.

In places, the quartz carries 3 to 4 ounces of gold to the ton, and in rare cases, as in a shallow pit near Arbacoochee, Cleburne county, a value of £416 ($2,000) per ton has been recorded. But these instances are extremely rare, and experience has shown that such rich ore cannot by any means be depended upon. It is very doubtful whether any quartz-reef in the state will yield as much as ½ ounce per ton on regular operations, and the average will be closer to ⅓ than to ½ ounce. The fact that gold-mining in the modern sense of the term does not now exist in Alabama, the operations being confined to two or three mills, prevents one from saying much about the matter. There is not a mine in the state that is worked to a depth of 100 feet, so that assays of the ore taken from the upper parts of the reefs cannot be said to represent

the ore proper. The decomposed part of the ore is soon exhausted, and with it the part that gives the best assays and that lends itself readily to ordinary amalgamation. What deep mining will reveal no one can assert, but if the rule which holds good on similar ore elsewhere will apply here, certainly the free-milling ore will give place to sulphide ores below water-level. Then it becomes a question of concentration and chlorination, for the free-gold alone will not pay expenses.

This much, however, may be said, that there are many quartz-reefs practically untouched that carry from 16s. 8d. to 25s. ($4 to $6) a ton regularly, and some contain stringers and chimneys of much greater value. These reefs to depths of 40 to 60 feet are composed of friable quartz, easily crushed, and all of the gold is free. A 25s. ($6) free-milling ore is not to be despised, and from considerations of climate, labour, timber, and fuel, it is believed that a 16s. 8d. ($4) ore can be profitably worked. Ordinary labour is paid 3s. 1½d. (75 cents) a day, blacksmiths and carpenters, 6s. 3d. ($1·50), sawed lumber, 29s. 2d. ($7) per thousand feet, and cord-wood, 3s. 4d. (80 cents) per cord, delivered and stacked. Out-door work goes on every day in the year, and severe weather is unknown. Alabama has the distinction of producing the cheapest pig-iron in the world, not only because of the proximity of the raw materials to each other, but also and especially because of the cheap ore. The ore necessary for the production of 1 ton of iron can be and has been put into the stock-house for 4s. 7d. ($1·10) and it is this fact that has enabled our iron-masters to hold out in the face of long continued depression.

This state could also enter the list of gold-producers, and maintain a respectable position by means of her low-grade gold-ores. These are the decomposed schists (or gneisses) carrying from 4s. 2d. ($1) to 10s. 5d. ($2·50) a ton, which can be mined and delivered for 10d. (20 cents) a ton. They carry no sulphide ores, all of the gold is free, and for the most part coarse; flour-gold is seldom met with, although present now and then. The occurrence of this decomposed rock is so peculiar, that a brief description of a typical deposit may not be out of place. In Clay county, there are enormous beds of decomposed schist, or gneiss, that run across the county in a general north to east course, dipping towards the south-east. The underlying rock is a fine to medium-grained gneissoid schist, probably of Lower Silurian age, very tough and hard below water-level, but comparatively soft to depths of 30 and 40 feet. These beds are traversed by quartz-seams of varying thickness, from a knife edge to 30 inches, for the most part interbedded, but not infrequently cutting the schist at innumerable angles. These quartz-seams do not always

carry gold, but now and then they are worth mining, and in a few cases are fairly rich, carrying from ½ to 1 ounce of gold per ton. The decomposed schist carries the gold, and not the quartz, although quartz is invariably present when the pan shows colours of gold. The schists may be classified under four heads:—(1) micaceous, (2) graphitic, (3) manganiferous, and (4) garnetiferous; the classification depending on the predominance of mica, graphite, manganese stains, and iron garnets. No hard-and-fast line can be drawn between these classes of ore, as they shade into each other imperceptibly, often appearing on the same property, and to some extent in the same opening. In addition to the schists there is also found a decomposed felspar which carries free gold, the kaolinization having progressed so far as to leave the rock, near the surface at least, soft and friable, breaking easily under the hammer, and panning white. A similar occurrence, *i.e.*, partially kaolinized felspar carrying free gold, is to be seen at the Boilston mine, Henderson county, North Carolina, as noticed by the writer several years ago.

Of the four classes of ore the most striking and perhaps the most valuable is the garnet-schist, a decomposed gneissoid schist of deep red colour, and full of iron garnets, some of them as large as a man's fist. The free gold begins at the surface, the earth adhering to the roots of grass and maize, giving fine colours in the pan. The perfectly solid garnets do not seem to carry gold, but when they are partially decomposed and fissured, the exterior and the cracks being filled with deep red ochre, they are often rich. At depths so far reached, 30 to 40 feet, the garnets are plentifully sprinkled in the earth and schist, following no lines of deposition, but lying as raisins in a cake. The entire mass of soil, earth, decomposed schist in place, garnets and thin seams of quartz, to a depth of at least 35 feet, can be mined and sent to the mill. The value of the ore varies from 4s. 2d. to 10s. 5d. ($1 to $2·50) a ton, and as it can be mined and delivered to the mill for 10d. (20 cents) and milled for 1s. 3d. (30 cents), there is a fair opportunity for profitable working.

There is at present one 5 feet Huntingdon mill in successful operation, handling 20 to 25 tons per day of 24 hours, and using a decomposed manganiferous schist carrying from 4s. 2d. to 10s. 5d. ($1 to $2·50) a ton in free gold. The writer is at present putting in a 5 feet Huntingdon mill to work a mixture of micaceous and garnetiferous schist of about the same value.

The accompanying sketch-map of the gold-bearing regions of the state (Fig. 1, Plate III.) and of Clay county (Fig. 2, Plate III.) may be of some interest.

To illustrate M.W.W.B. Phillip's Paper on "The Gold Region of Alabama, U.S.A."

FIG. 1.

SKETCH MAP

OF

ALABAMA, U.S.A.

Scale, 90 Miles to 1 Inch.

REFERENCES.

COAL-MEASURES

CRYSTALLINE ROCKS (GOLD-BEARING)

RAILWAYS

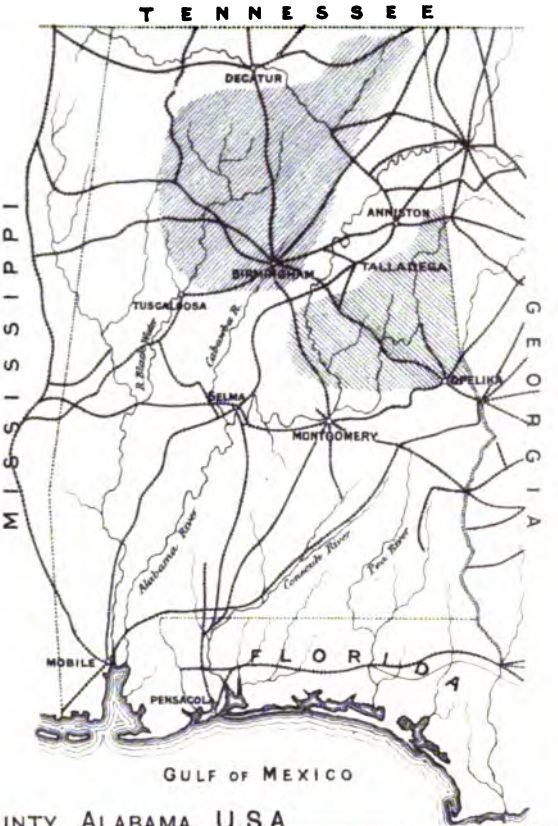


FIG. 2.

SKETCH MAP OF CLAY COUNTY, ALABAMA. U.S.A

Scale, 6⅔ Miles to 1 Inch.

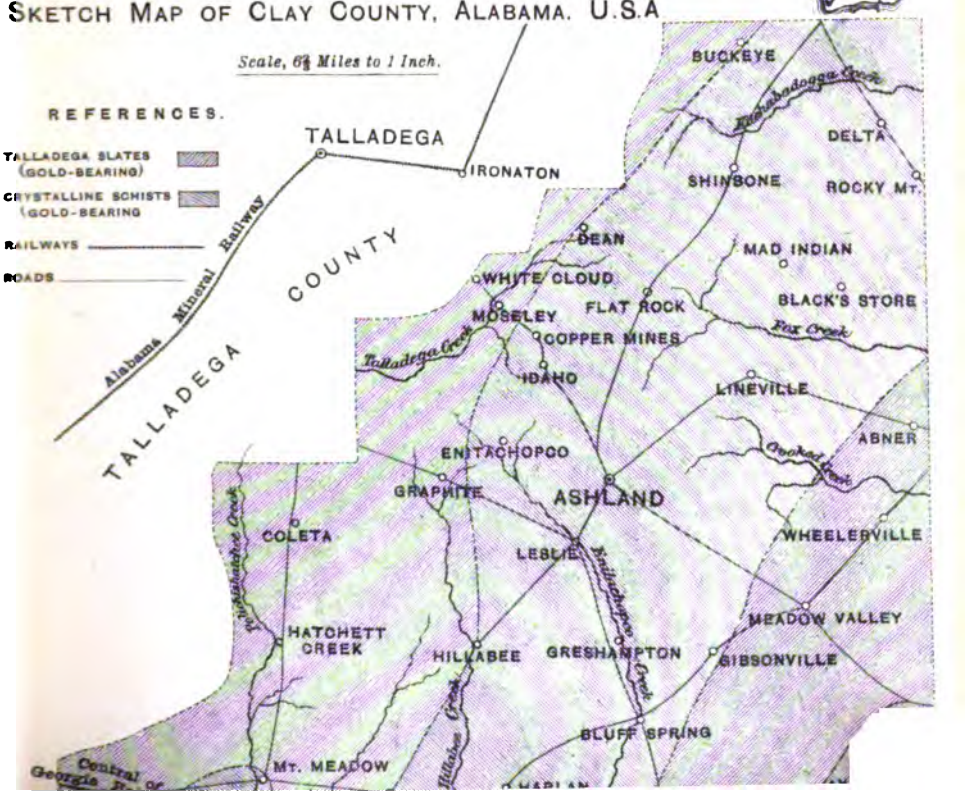
REFERENCES.

TALLADEGA SLATES (GOLD-BEARING)

CRYSTALLINE SCHISTS (GOLD-BEARING)

RAILWAYS

ROADS



At present, the county suffers from lack of railway facilities, the nearest station being 10 miles away, and the road none of the best. The farming interests are somewhat backward, but the soil is fertile and well adapted for all the crops of the Southern States. Grapes, berries, and all kinds of fruits thrive excellently well. The country is hilly and well watered, and the climate is all that the most fastidious could reasonably desire.

This brief description of what promises to be a profitable gold-mining district is given with no thought of "booming" Alabama gold-mines. There are no bonanzas here, but the returns to well-ordered business management are certainly attractive.

Alabama has become known as a coal- and iron-producing state within the last 10 or 15 years, but there are not many who are aware that she could also produce gold profitably. Such, however, is the case, and it is hoped that this brief paper, which is hardly more than a note, may arouse at least professional interest in the subject.

DISCUSSION ON MR. BROMLY'S "NOTES UPON GOLD-MINING IN BURMA."*

Dr. FRITZ NOETLING (Calcutta) wrote that it must appear rather strange that Burma has always been noted for its mineral wealth, though in the light of recent researches, the fame thus acquired seems to be considerably exaggerated. Gold, particularly, was said to occur in large quantities, and there seems to be no doubt that the gilded pagodas scattered in countless numbers all over the country, have done much to support this view. Now, we know almost for certain that the occurrence of gold in Burma is very limited, at least as regards its occurrence in paying quantities. The frequent occurrence of the Burmese word *shwé* (= gold) in connexion with the names of villages or small streams is very deceptive, because on closer examination it will almost always be seen that in such localities gold was washed from the sand in an erratic manner during the off season.

So far, the only part of Burma where gold seems to occur in veins containing it in workable quantities is Wuntho in Central Burma. When Wuntho was finally occupied, a number of prospectors flocked to the district, prospecting licenses were issued, but although expectations ran

* *Trans. Fed. Inst.*, vol. xii., page 506.

high at the beginning, it seems that only a single concern has met with some success. He (Dr. Noetling) examined the auriferous tract early in 1893, when Choukpazat was still in its infancy, that is to say, it had not got beyond the prospecting stage yet. The dense jungle made any examination extremely difficult, and he was therefore only able to form a general idea about the occurrence of the gold. It is therefore very useful that Mr. Bromly, who knows Choukpazat from his own experience, has taken the trouble to write the above-named paper, which considerably increases our knowledge of the occurrence of gold in Burma. His own (Dr. Noetling) observations with regard to the geology have, so far, been fully confirmed. The information on the working of the ore, and on the cost of labour, which he (Dr. Noetling) could fully bear out from personal experience, form a particularly interesting feature of Mr. Bromly's paper. He (Dr. Noetling) might, however, add that Wuntho is an exceedingly feverish country, and that skilled European labour will have eventually to be paid much higher than at present, because there will be very few who will be able to stand the heat and the strain of the fever-breeding jungle.

DISCUSSION ON PROF. DE LAUNAY'S "GEOLOGICAL DESCRIPTION OF THE GOLD-MINES OF THE TRANSVAAL."*

Mr. Edward H. Clifford (Johannesburg) wrote that Prof. De Launay assumed that both the pyrites and gold were deposited at the same time as the pebbles, and that some portion of both were precipitated from solution. If this be so, why should the sandstone immediately next the reefs be almost free from both pyrites and gold in the majority of cases? And how is it that gold is not generally concentrated in the lower parts of the beds? Prof. De Launay tentatively put forward the theory of marine origin, on account of the position of the series between marine fossiliferous beds, its area, and the frequent presence of flattened pebbles. With regard to area, the gravel deposits of some Asiatic rivers already cover areas of thousands of square miles, and the marine beds lying above and below the series are both unconformable, and prove nothing in this connexion.

* *Trans. Fed. Inst.*, vol. xi., page 378; and vol. xiii., page 122.

With regard to the origin of the contents of the reefs, Prof. De Launay assumed that, so far as the silica was concerned, fragments of all kinds of rocks had been subjected to such attrition that only quartz had survived. The rolled pyrites, on the other hand, could not have travelled far, and owing to its friable nature, would have been obliterated in case of any such attrition *in situ*, as must be assumed in the case of the quartz. Prof. De Launay said that gold was never found in the pebbles except in fissures; this was incorrect, as both gold and pyrites were occasionally found in pebbles in such a way as to leave no doubt that they were already present in the original rock.

The meeting was then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
OCTOBER 9TH, 1897.

MR. GEORGE MAY, PRESIDENT, IN THE CHAIR.

Mr. G. B. FORSTER said that since the last meeting of the Institute he regretted to announce that they had lost an old and very valued member and a past vice-President of this Institute by the death of Mr. T. J. Bewick, which took place recently. He proposed that the Secretary be instructed to write a letter of sympathy to his son, Mr. T. B. Bewick, and say how much the Institute condoled with him and regretted the loss which he as well as the members had suffered by his father's death. Mr. Bewick was a man who was well known and highly respected. He was endeared to those who knew him by his amiable and straightforward conduct, and as a professional man, his superior attainments and great capabilities enabled him to take the high position which he held as a mining engineer.

Mr. T. W. BENSON, in seconding the proposal, said that as an old friend of the late Mr. Bewick, he could thoroughly endorse every word which had fallen from Mr. Forster. Mr. T. J. Bewick had always taken the greatest possible interest in the affairs of this Institute, and until his removal to the south of England he attended all the meetings perhaps more regularly than almost any other member. The deceased gentleman might not perhaps be so well known to the younger members, but for the past 35 years he had been a valued member and always took an active interest in the affairs of the Institute, which would be a great loser by his death.

The motion was unanimously adopted.

The minutes of the last General Meeting were read, and the proceedings of the Council at their meetings on September 25th and that day

were reported, together with the proceedings of the Council of The Federated Institution of Mining Engineers on September 14th.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. WILLIAM EDWARD CAYLEY ALEXANDER, Mining Engineer, Lynton House, Hampstead Lane, Highgate, London, N.

Mr. ANDREW H. BOWMAN, Chief Mining Engineer, McClure Coke Company, Scottdale, Westmoreland County, Pennsylvania, U.S.A.

Mr. GEORGE HERBERT BROOME, Managing Engineer, The Westport Cardiff Coal Company, Limited, Seddonville, *via* Westport, New Zealand.

Mr. ERNEST JAMES COCHRANE, Electrical Engineer Electric Light Works, Coolgardie, Western Australia.

Mr. JOSEPH COOK, Jun., Mechanical Engineer, Washington Iron Works, Co. Durham.

Mr. SYDNEY FAWNS, Mining Engineer, Coolgardie, Western Australia.

Mr. CHARLES GREGORIE, Mining Engineer, Aberdare, South Wales.

Mr. EDMUND LOUIS HOPE, Mining Engineer, Dandot, Jhelum, Punjaub, India.

Mr. CHARLES WARREN BOWEN JENKINS, Mining Engineer, Venture Syndicate, Perth, Western Australia.

Mr. JOHN DYER LEWIS, H.M. Inspector of Mines, 183, Richmond Road, Roath, Cardiff.

Mr. H. W. MARTIN, Mining Engineer, Trewern, Dowlais, Glamorganshire.

Mr. THOMAS ALOYSIUS O'DONAHUE, Mining Engineer's Assistant, 35, Princess Street, Wigan.

Mr. STEPHEN ROGERS, Mining Engineer, 27, Ferris Town, Truro, Cornwall.

Mr. JOHN R. WAGNER, Mechanical Engineer and Superintendent of Tests, The Cross Creek Coal Company, Drifton, Luzerne County, Pennsylvania, U.S.A.

Mr. HENRY BLAIR WALKER, Colliery Manager, Die Rietfontein Colliery, *via* Springs, Johannesburg, Transvaal.

Mr. FREDERICK HERBERT WHALLEY, Civil and Mining Engineer, Queen Street, Auckland, New Zealand.

Mr. JAMES YOUNG, Mechanical Engineer, 19, Wentworth Place, Newcastle-upon-Tyne.

ASSOCIATE MEMBERS—

Mr. GEORGE P. CHAPLIN, 124, Breakspear's Road, Brockley, London, S.E.

Mr. BERKLY GILLESPIE DICKSON, Irura, Tolosa, Spain.

Mr. JOHN GRAHAM, Findon Cottage, near Durham.

Mr. ARTHUR HODGETTS, 100, Smith Street, Durban, Natal, South Africa.

Mr. EDWARD JOBSON, 5, Bath Terrace, Tynemouth.

Mr. WILLIAM THOMAS REES, Maesyffynon, Aberdare, South Wales.

Mr. EDWARD STEPHEN REVETT, 32, Old Jewry, London, E.C.

Mr. WILLIAM MURRAY ROBERTS, P.O. Box 42, Barberton, Transvaal.

Mr. ALBERT TUNNINGTON, Mawson's Reward Company, Dundas, Western Australia.

STUDENTS—

Mr. JOSEPH PERCIVAL HALL, Mining Student, Cornsay Colliery, Durham.
Mr. JOHN STRAKER NISBET, Mining Student, Cramlington Collieries, Northumberland.
Mr. SYDNEY RICHARDSON, Mining Student, South Pelaw Colliery, Chester-le-Street.

SUBSCRIBERS -

Messrs. JAMES JOICEY AND COMPANY, LIMITED, Newcastle-upon-Tyne.
Messrs. THE LAMBTON COLLIERIES, LIMITED, E, Queen Street, Newcastle-upon-Tyne.

DISCUSSION UPON MR. W. GALLOWAY'S PAPER ON "SECONDARY HAULAGE."*

Mr. FRANK R. SIMPSON pointed out that Mr. Galloway, in replying to the discussion on his paper, compared the cost of his secondary haulage for a distance of 581 yards with the cost of pony-putting in this district. He (Mr. Simpson) did not think that it was usual in the North of England for putting to extend so far as that. This length would be at the worst 250 yards, and he thought that the cost assumed by Mr. Galloway should be considerably lessened. He thought also that in the North of England it was almost impossible to adopt any system of secondary haulage which would reduce the cost of handling the tubs separately. It was not motive power which constituted the principal expense of pony-putting but the cost of handling the tubs separately, and that would be true of any system of face-haulage. In the case of endless-ropes, where the rope happened to be underneath the tub, there was a convenient way of extending the haulage by carrying the ropes between a single line of rails beyond the main line where the double width was made.

Mr. J. H. MERIVALE thought that Mr. Galloway was to be congratulated on having mastered so satisfactorily the particular problem in which he was interested at his own collieries, but the system was hardly applicable to the conditions existing in this district. Mr. Galloway was dealing, he thought, with a colliery where the seams were dipping in-bye 1 in 24 ; he was also dealing with a large tub holding something like 2 tons of coal and, as Mr. Simpson pointed out, with a distance of about 600 yards, whereas the pony-haulage in this district was usually only a matter of about 150 yards. It seemed to him (Mr. Merivale) that any economy in the system of secondary haulage in this district must be

* *Trans. Fed. Inst.*, vol. xii., page 257 ; and vol. xiii., page 117.

sought on the lines which Mr. W. Lishman tried for some years (and from a mechanical point of view, with complete success) at the Lambton collieries, namely, with some form of locomotive (either compressed air or electrical). He did not see how any system of ropes could be carried into the working-places.

Possibly some of the members might have seen the recent proposal, or in fact the working model of a railway which might be adopted in mines, the idea being that great speeds could be employed. By the system to which he referred the lines were laid in hinged sections, and by hydraulic or other means, the ends of such sections were lifted in rotation, so that the trains were always running down hill. At first sight the idea seemed to be as impossible as that of sinking pits through running-sand by freezing the water, but they knew that this had been done; and who would say that it was impossible with level seams and with the power carried into the face (as would no doubt become the case when coal-cutters were more universally adopted) and with sufficient height to raise the tubs 1 foot, that such a system might not be carried out? The rails would be raised in sections, say, by compressed air and the tub run down, say, about 60 feet, and then the next section would be raised, and so on, and when the empty tub was brought back this process would be reversed.

But after all there was not such a great margin for economy as Mr. Galloway seemed to think. He compared pony-putting with ordinary haulage on engine-planes, and he put down the cost at 2½d. per ton-mile as against pony-putting at 2s. 2½d. per ton-mile.* These figures might be correct, but it seemed to him to be as fallacious as comparing the winding of coal by a winding-engine with the lifting of it into the tub by the hewer. They might as well say the cost of winding coal was 1d. per ton per 600 feet as compared with about £1 per ton for the same distance by the coal-hewer. The distance which the coal was put was very short; he believed 150 yards was something like the average rather than 250 yards, which Mr. F. R. Simpson referred to, and if they took Mr. Galloway's figures this would reduce the cost to about 2d. per ton, and although the slight reduction upon that was not to be despised (say, 10 per cent.), 10 per cent. on 2½d. per ton as compared with 10 per cent. on 2s. 2½d. was a very different thing. It must be remembered that the cost was not 2s. 2½d. per ton but 2s. 2½d. per ton-mile, a very different thing.

* *Trans. Fed. Inst.*, vol. xii., page 277.

Mr. FRANK R. SIMPSON said that he did not wish to convey the idea that 250 yards was the average length of pony-putting in the North of England; it would be a distressing thing in any case if they got so far as that.

Mr. T. E. FORSTER said that he quite agreed with the remarks of the previous speakers. When people started to compare things on a basis of the ton-mile, the comparisons were sometimes made in the most fallacious way. He thought to some extent that this was so in the case of the report of a committee of the North of England Institute of Mining and Mechanical Engineers on haulage;* what they ought to do was to take the work actually done. In South Wales, very large tubs were used, while in this district even an 8 cwts. tub was somewhat exceptional. The cost of hauling, driving, and putting was certainly much less than Mr. Galloway assumed, and such cost would in their case be altogether out of the question.

The PRESIDENT thought, however, that there was room for improvement in the North of England. The 150 yards spoken of as being the work of putting ponies, if it could be kept to that, would be very economical, and they could not very much improve upon it, but no doubt there was the question of dealing with the tubs after this 150 yards from the face and to the engine-plane. It was a difficult thing where they had a lot of districts to be able to get the hauling-ropes within 100 yards of the face. Mr. Galloway could not help them very much with their pony-putting, for they were very much better off in this respect than they were in South Wales. In the case of one of the collieries under his charge, compressed air and small haulage-engines were used to work small sets of tubs from the face to the main haulage-road. The compressed-air locomotives mentioned by Mr. Merivale could not be used to any great extent unless they had level roads. The difficulty was to some extent got over at a colliery in Yorkshire by an electric locomotive engine fitted with a hauling-drum. It was used to haul the tubs up the steep roads with a rope, and then became a locomotive on level roads.

Mr. FRANK R. SIMPSON said that the system of rope-haulage to which he referred was to take side by side two ropes between a single line of rails, the sets being gripped on in convenient numbers to either rope.

Mr. W. GALLOWAY wrote that it would have been much more satisfactory to him, as the writer of the paper, if Messrs. Simpson, Merivale,

* *Trans.*, vol. xvii., Appendix No. I.

and Forster had given figures taken from actual practice to illustrate their arguments, instead of contenting themselves with a series of general statements. The latter course did not bring us appreciably nearer to the desired goal, but left the subject as indefinite as it was before.

He thought that Mr. Merivale would, upon again looking at his paper, see that he (Mr. Merivale) had made a mistake when he stated that pony-putting was compared with ordinary haulage on engine-planes in that paper, as if the two things were in some sort comparable. He (Mr. Galloway) had endeavoured from the beginning to the end of his paper to keep the two things quite distinct, and to point out the fundamental differences between them. This was the reason why he had chosen the title "Secondary Haulage" for his paper, in order to distinguish it from what he called "primary haulage," and he thought that, under these circumstances, the charge would have to be withdrawn.

He (Mr. Galloway) had made a comparison between two systems of secondary haulage, for each of which he had exact data. One of them was in the act of being introduced under adverse circumstances: the gradients were, in many places, against the load, and in some places so steep that pony-putting would have been impossible; the districts were small and scattered, for the reasons explained in the paper; and the officials were more or less indifferent, and hankered after horse-haulage. The other system had been in use for many years, and had been brought to the last degree of perfection of which it was capable under the fostering care of world-renowned engineers and managers, and in a coal-field and under circumstances in which every condition appeared to be favourable to it.

He did not for a moment pretend or wish it to be understood that he considered the use of small engines, wire-ropes, and large tubs to be a final and conclusive solution of the question of secondary haulage. It might or might not ultimately prove to be a link in the chain of evolution. He thought that he had been able to show that it could at least hold its own, even when working under the unfavourable conditions which he had described, when pitted against pony-putting working under favourable conditions. The conclusion seemed to be inevitable that, given the same conditions in both cases, the small engines, wire-ropes, and large tubs were the more economical. He was however open to conviction, and all he asked for was a statement of facts and well authenticated figures, and not opinions or generalities.

He might say in conclusion that his own early experience was with small tubs carrying, some 6 cwts., others 12 to 14 cwts., and that when he

first came in contact with large tubs carrying from 25 to 40 or even 45 cwts., he felt as much prejudice against them as anyone could have had who had spoken during the discussion. But as time went on his views had gradually undergone modification, until at length he felt quite unable to appreciate the supposed advantages of the small tub. The argument as to derailment had a plausible ring about it that was not borne out by the results of practical working. A moderate degree of care in laying the roads, providing rails of sufficient strength for the weight to be carried, regulating the curves to suit the gauge of the rails, and having the flanges of the wheels deep enough to correspond to their diameter and to the radii of the curves, reduced the numbers of derailments to a very small figure. Heavy tubs ought never to be handled by men except upon falling gradients; and mechanical appliances ought to be used upon a dead level and on all rising gradients. If these fundamental rules are attended to, the employment of heavy tubs becomes as simple and of as easy application as that of light tubs. For instance, at the top of a shaft the writer has handled 800 tons per day (including stoppage on the weighing-machine and tipping), with tubs carrying on the average 2 tons of coal each, by means of 3 men and a boy—one of the men acting as banksman and giving all the signals. Three men did all the work at the bottom of the same shaft at the same time. The tipping was, of course, done by mechanical power, and the empty tubs were raised to a height of 6 feet or so on an inclined plane, worked by means of a chain with knobs fixed on it at certain distances apart which caught behind the axles of the tubs automatically, and after pushing them up to the top of the incline released them automatically and allowed them to run round to the back of the shaft on a downward gradient.

The writer thinks that there cannot be two opinions as to the advantages of a large tub, both on engine-planes and in winding. The only refuge left to the advocate of the small tub is, therefore, in secondary haulage, and that refuge (as the writer has endeavoured to show in his paper) does not appear to be a very secure one.

The following paper was read by Mr. G. B. REYNOLDS on "A Method of Dealing with Running-sand when met with in Borings":—

A METHOD OF DEALING WITH RUNNING-SAND WHEN MET WITH IN BORINGS.

By GEO. B. REYNOLDS.

The difficulty experienced on meeting with sand in boring operations at any time is considerable, as sand, when wet as it usually is in such cases, presents great resistance to the insertion of the casing, and if attempts be made to drive it down, the casing may collapse or telescope. Further, it may happen that the engineer conducting the boring operations may have no more casing on the ground than will be sufficient, without accidents, to finish his borehole, and if abroad, some months' delay will result if he alters the size of the hole, owing to inability to buy the tubes he may, under the altered circumstances, now need.

Under conditions resembling those mentioned above the author adopted the plan which he will now describe, and he hopes that the method may prove of as much use to others as it was to him. Recourse was had to the expedient about to be described when the author was conducting boring operations for the government of India in proving the Warora coal-field in the Wardah Valley of the Central Provinces. Th method successfully adopted in India may be of use anywhere where the strata are soft and sandy, and calculated to cause trouble in boring.

At Warora, the strata overlying the Coal-measures consist of soft sandstones and clays, and the upper coal-seam is overlaid by a seam of fire-clay about 10 feet thick.

It was expected to strike the white sandstone in the hole where the running-sand was met, at a depth of about 900 feet, after which it was considered useless to bore further in search of coal. This, then, was assumed to be the limiting depth of the hole, and the boring was arranged for accordingly.

Knowing that serious loss of time would follow any stoppage of boring work for want of tubes—and desiring to leave no tubes in the hole when it was finished, but to withdraw them all—the tubes first inserted were made at the shop at the mines on the Lentz method as used at Baku.*

In putting down these tubes, which could not of course, from the nature of their construction, stand much driving, the running-sand was

* *Petroleum and its Products*, by Mr. Boverton Redwood, 1896, vol. i., page 286.

found, and they were forced into the sand by blows of a monkey as far as was deemed safe short of telescoping them. These tubes were some 12½ inches in diameter, and when driven down as far as possible, steel tubes, flush jointed (10 inches in diameter), were inserted and driven into the sand, as far as possible, in advance of the larger tubes.

It was desired to force a grouting of Portland cement through the inner tube, allow it to set, and then to drill through the sand, which would be, it was hoped, solid and self-supporting when cemented by the cement.

Two methods of pumping the cement grouting into the sand below the casing may be used. The first method is to put a cap on the top of the tube through which the cement is to be forced, and to connect this cap by a pipe with a donkey-pump, and so force in the liquid grouting. This method was not adopted, as a certain amount of delay would be involved in making the cap so needed, none being procurable ready made.

The second method is to use the tubes as a pump-barrel, the boring rods as pump-rods, and on these last to fix an inverted pump-bucket of wood with leather clack-valves, and so pump the water standing in the tube downwards, with the cement, into the sand below. A reciprocating motion is given to the rods by the drilling-engine, and they are weighted with tubes to enable the bucket to force the water down. The expedient was a rough one, but answered its purpose, and had the merit of needing only such simple appliances as could be readily made by an ordinary native blacksmith and carpenter on the spot.

Had these ready means not been effectual, the author would have had recourse to the former method, which would have been more expensive and caused delay.

To prevent the grouting from rising between the inner and the outer tubes, and so diminishing the head caused by the pumping, soft, dry wooden wedges were driven, at the top of the outer tube, into the annular space between the two tubes, and thus reduced any loss to a minimum.

The sand, in the instances under description, was found at only a small depth from the surface, but the method is applicable at whatever depth the sand may lie, and requires only the insertion of a tube a short length into the sand down which the cement can be pumped.

The idea was, the writer thinks, suggested to him by reading the articles by Mr. W. R. Kinipple, in *Engineering* of May 20th and 27th, 'Underpinning by means of Grouting and Stock-ramming,"* and he trusts that the method may be of use to others.

* Vol. liii., pages 609 and 646.

Mr. A. L. STEAVENSON asked what was the thickness of the sand, and whether, when the hole got through the cement, the boring was continued. There was one system of boring through sand (which the writer had not mentioned) by forcing water down under pressure, which washed up the sand and allowed the pipes to go quickly down. He also asked how far the cement passed into the sand below: did they bore through the cement afterwards, or did the cement simply cake round the bottom of the tube?

Mr. T. E. FORSTER said that it appeared to him that the cement was pumped down the inner tubes and united with the sand into solid stone, which was then bored through.

Mr. F. COULSON said that it would be interesting to know the thickness of sand below the bottom of the pipes, and whether there was any pressure of water coming from the sand. The system of putting cement into bore-holes had been adopted, to his knowledge, for 30 years for securing loose ground, but he could not imagine, in the case of quicksands where there was not much water, that it would be possible to force the cement any great distance into it. It would set hard for a certain distance, but there would be again the quicksand below to contend with. In addition, there were some kinds of water met with in bore-holes in which cement would not set, although tried with all kinds of cement in many different ways. As Mr. Steavenson had suggested, possibly the best known method of getting through quicksand was to force water down under pressure and rotate the pipes, and they would go down very rapidly.

Mr. G. B. FORSTER suggested that the forcing down of the cement was probably repeated if the thickness of the sand required the treatment. He had pleasure in proposing a vote of thanks to the writer of the paper.

Mr. MERIVALE seconded the proposal, which was cordially adopted.

Mr. G. B. REYNOLDS, replying to the discussion, wrote that the thickness of the sand was, as far as his memory served him, 12 or 14 feet. Above the sand there was a seam of clay, and when this was pierced by the boring-tools the water rose about 15 feet in the staple-pit in which the men were working. This pit was 18 feet deep below the surface of the ground, so that to continue boring a donkey-pump, which was worked as occasion required, was placed in the pit, till, with the advance of the hot weather, the water took off. The sand being so full of water, no difficulty was experienced in forcing into it the cement-grouting. If the cement did not reach the lower limit of the sand, there

was no difficulty in repeating the process as often as necessary where the drill proved that the sand was not self-sustaining. Had there been no water, or but little water, in the sand, it would have been easy to add water in excess to the cement at the top of the hole and pump it down. The boring was continued to a depth of over 650 feet below the bottom of the sand. The hydraulic system of boring alluded to by Messrs. A. L. Steavenson and F. Coulson was known to him (Mr. Reynolds), but he had not the necessary appliances at hand, and so adopted the ready method which he had described in his paper. The gist of the paper was the description of a cheap and ready method of dealing with the sand, and one not involving any special plant.

The following paper by Mr. W. L. Austin on "Pyritic Smelting" was taken as read :—

PYRITIC SMELTING.

By WM. LAWRENCE AUSTIN, Ph.D., of Denver, Colorado, U.S.A.

Introduction.

Under pyritic smelting is understood a smelting process which aims at utilizing the calorific power of an ore.

Pyrite (FeS_2), chalcopyrite ($CuFeS_2$), pyrrhotite (Fe_7S_8), arsenopyrite (FeAsS), blende (ZnS), galena (PbS), etc., are all ores which have calorific values as metallurgical fuels, and it is with the utilization of this quality in such ores that pyritic smelting has to do.

When a smelting ore contains in itself the fuel necessary for its concentration into a product which can be transported to market and sold at a profit, that the most rational way to beneficiate it is to turn this property to account, would seem to be so self-evident a proposition as not to admit of argument. Yet the common practice is to destroy such natural fuels by calcination, and then smelt, with the help of coke, etc., the oxides thus produced.

Why should we burn (roast) an ore which contains in itself a sufficient quantity of potential heat units to smelt it, and then smelt the burnt product with the assistance of more or less expensive fuel? Or, even when such an ore is smelted raw, why should we melt it down with coke —as if it were pig-iron for foundry purposes—although we may have dispensed with the preliminary roasting? In either case such a proceeding must be considered as wasteful and extravagant, if it can be shown that a heavy sulphide ore contains in itself a source of heat which, when properly applied, will suffice for maintaining a smelting temperature.

One would not think of employing wood to keep up a coal-fire after it has once been started, for we all know that when the coal has been kindled, that is to say, when once the temperature has been raised to a point at which the elements composing what we term coal are able to unite with oxygen, then the mineral continues to burn of itself and any addition of wood becomes superfluous. The same is the case with iron pyrites. When this mineral has been raised to a temperature at which its component parts are free to unite with the oxygen of the air, further use of kindling is equally as unnecessary as in the case of coal, and in the proper apparatus the combustion can be made self-sustaining.

We see this statement verified in the every-day practice of heap-roasting. In this process, pyrites is placed on kindling, and covered with fine material so as to make it possible to regulate the admission of the air to the pile. Once ignited by the kindling, the whole mass continues to burn until the sulphide is practically converted into oxide, so far as the imperfections of the method of treatment will permit. In the modern pyrites-burners used by sulphuric acid manufacturers, the oxidation is much more thorough than in open-air heap-roasting, and no kindling is necessary after the kiln becomes sufficiently heated. But in either case, the combustibility of the pyrites itself is relied upon to accomplish the end in view, and the carrying out of these processes demonstrates that once ignited pyrites will continue to burn until the sulphur is practically all eliminated and the iron is converted into oxide. It only remains, therefore, to burn the pyrites more rapidly in order to produce a temperature which is high enough to fuse the whole mass, and this actually takes place unless care is exercised in restricting the amount of air admitted to the kilns.

Pure iron pyrites is a compound of iron and sulphur in the proportions by weight of 46·66 of iron to 53·34 of sulphur, and both of these elements may be burned in air when the proper conditions are provided to effect their combination with oxygen. Everyone knows that sulphur will burn, but the layman is often disposed to accept with incredulity the statement that iron can be utilized as a fuel. That the metal of which modern fire-proof buildings are so largely constructed is capable of burning with a fierceness which rivals that of coke, is to him an utter absurdity. Still he knows that when an iron bar is heated to a high temperature in a forge, it will burn and emit brilliant sparks. In burning iron much depends upon the extent of surface exposed to the action of the air. A heavy bar with a surface relatively limited as compared to its bulk can only be made to burn with difficulty under ordinary conditions; but finely divided iron, prepared in a chemical way, will catch fire of itself if exposed to the air; * and iron in the state in which it exists at the instant when it separates from the sulphur with which it is combined in iron pyrites, ignites even more readily. Metallic iron is, therefore, a combustible, and all that it is necessary to do in order to burn it, is to provide the necessary apparatus for carrying out the operation in conformity with the laws governing the use of this class of fuel.

* According to Magnus, metallic iron may be reduced from ferric oxide by hydrogen gas at a temperature lower than the boiling-point of mercury. This iron is a black powder, and is so pyrophoric—on account of its porosity—that it catches fire in the air and burns.

However, the combination of iron and sulphur in iron sulphides of whatever class is not a combustible so long as the two elements are united. They must first be dissociated from each other in order to be free to enter into combination with another element, and it is only after such dissociation has been brought about, and the two elements find themselves in *status nascendi*, that their combustion may be effected. To dissociate these elements from each other, a certain amount of mechanical work must be done, and in the pyritic furnace this work is performed by heating the compound up to a certain point, when the elements separate from each other, and, if the proper amount of oxygen be then provided, they will unite with it. When suitable apparatus is used for carrying out the combustion of iron sulphide by forcing its elements into combination with the oxygen of the air, the heat generated is sufficient to fuse the resulting ferrous oxide, carry off the sulphurous acid gas produced by the burning sulphur, and at the same time to effect the dissociation of the next portion of the sulphide to be operated upon. If silica be present to make a fusible slag with the molten ferrous oxide thus formed, then the sulphurous acid gas passes upward with the heated nitrogen, and the molten slag falls downward into a vessel prepared for its reception, and we have a smelting operation. When means have been taken for supplying the proper proportions of air and pyrites in a manner conforming to the conditions under which they can best unite, the smelting will not differ materially, so far as the appearance of the furnace is concerned, from the usual operation with coke or charcoal, only in this case the pyrites supplies both the fuel and flux.

That iron pyrites contains in itself the potential heat units requisite for its own smelting may be demonstrated by thermal calculations,* or ocular evidence of the fact may be obtained by observing a Manhès converter in operation. In the so-called bessemerizing of copper-matte (a process in such general use at the present time as not to require detailed description here) the molten iron sulphide is run into a converter, and air is blown through it until practically all the iron is burned off, the combustion of the iron (and incidentally of the sulphur associated with it) sufficing to keep the mass at a high heat and extremely liquid during the operation. Anyone who has watched the working of such a converter can have no longer any doubt about the fuel qualities of iron sulphide, for the treatment of matte in these vessels is actually a smelting operation, although of limited duration

* For thermal calculations on pyritic smelting, see the *Berg- und Hüttenmännische Zeitung*, 1894, vol. liii., page 217.

owing to the unsuitability of the converter for a continuous smelting of ores. That it is not, as many think, wholly the sulphur which supplies the heat is shown by the fact that the sulphide treated in these converters is largely iron monosulphide (FeS). Hence it is evident that the iron pyrites (FeS_2) after losing one atom of sulphur in a preliminary melting still retains more than enough potential heat units to suffice for a smelting operation. In fact, iron pyrites reduced to the form of matte and deprived of 50 per cent. of its sulphur is a better fuel for smelting purposes than was the original ore, for the raw ore possesses the quality of decrepitating, and flies to pieces when heated, causing dust troubles when precautions are not taken to obviate this difficulty, whereas the matte melts down quietly, and is for that reason more desirable. On account of the fuel qualities possessed by matte it can be used to smelt a charge of siliceous ore, proper consideration being had for the relative proportions of iron and silica necessary in forming an easy melting slag.

What has been said in regard to iron pyrites and matte as fuels, applies equally to any of the combinations of iron with the metalloids of the sulphur group (sulphur, arsenic, or antimony), and in a measure also to their combinations with zinc, lead, copper, etc. Pyrrhotite, arsenopyrite, chalcopyrite, marcasite, speiss, etc., are all suitable for treatment by the pyritic smelting-process.

If, as has been shown above, iron pyrites contains in its combustible elements a sufficient quantity of potential heat units to support a smelting operation, then the use of carbonaceous fuel to smelt such ores is sheer waste, provided a suitable apparatus can be obtained for turning this quality to economic advantage. Assuming for the present that such an apparatus is at hand, then the beneficiation of deposits of this mineral, so low in grade as not to permit of profitable treatment by metallurgical processes heretofore in use, is rendered possible by the fact that it is no longer necessary to carry expensive fuel to them, nor to transport such ores to smelting centres where cheaper fuel is available, for they can be handled much more economically at the mines themselves.

Pyritic smelting should be regarded, not as a smelting process in the usual acceptance of the term in the western portion of the United States, involving all the complicated operations ore is subjected to in the large smelting establishments at Denver, Kansas City, Omaha, and elsewhere, but it should be looked upon as a method of cheap concentration (fire-concentration is an appropriate term), and pyritic smelting-plants will

find their proper sphere when placed on the dumps of those mines whose ores are suitable for treatment by this process. Such a fire-concentrator situated at the mouth of a shaft or tunnel, so that the ore could be run out from the mine in mine cars and dumped into the shaft of the furnace without further handling, would naturally effect a great saving in the expense of operating such properties. If the freighting, crushing, sampling, bedding, calcining, and coke-smelting of low-grade ores were done away with, it is evident that the expense of treating them would be greatly reduced. In handling low-grade concentrating ores, where water is used for concentration, the raw ore is dumped into the concentrator, and an effort made to produce a concentrated product at the minimum of expense. Why make an exception in the case of fire-concentration and encumber it with so many unnecessary details? Or why should the owners of deposits of this class of ore continue to pay high transportation and smelting charges, which often render the working of their mines unprofitable, when it lies in their hands to concentrate their values at the mines before shipping, exactly on the same general plan as the values of low-grade siliceous ores are often concentrated in wet-concentration mills? In a well-managed mine the excavation of the ore is controlled by assay in any case, so that its value is known before it is mined, and thereby the cost of taking out worthless material is avoided. Such preliminary assaying is all that is necessary where a fire-concentrator is used, and there is no reason why the crude ore, just as it is mined, should not be dumped into the hoppers of a fire-concentrator, as it is dumped into the rock-breakers of a wet-concentration mill. This is admissible in pyritic smelting, although it might be considered unadvisable in other smelting methods. To make this point clearer we will consider the characteristics of the two methods of smelting.

In the case of an ordinary lead- or copper-smelter we have a mass of inert mineral matter which we fuse down into various furnace-products by the help of carbonaceous fuel. The charge remains in the shaft of the furnace, until the carbonaceous matter has been burned up and the ores and fluxes brought into a state of fusion. We can, therefore, calculate with safety that the elements contained in the charge shovelled into the top of the stack will group themselves according to known laws into slag, bullion, matte, etc., which will be found in the crucible of the furnace arranged in the order of their specific gravities. But in pyritic smelting the case is entirely different. The ore and the fuel are one, and just how much of the iron contained in the iron

sulphide will be burned to oxide and how much will be left as matte is wholly a matter of furnace conditions. The relative proportions of the elements in the furnace-charge are, within certain limits, of minor consideration, as the furnaceman has it in his power to alter the proportions of matte and slag issuing from the furnace, regardless of the actual chemical analysis of the charge. For this reason ore-bedding is superfluous, and the furnaceman by changing the heat or pressure of his blast, and by the addition of more or less siliceous material, or by modifying certain other conditions, can regulate the relative amounts of matte and slag to suit his wishes. By allowing for the proper subsidence of the molten products, that is, by giving them time to separate, and by looking after the specific gravity of his slag, the latter can always be kept sufficiently clean. So that the whole matter resolves itself into one of practical experience with this particular method of ore-treatment, the operations being guided by the eye rather than by chemical analysis.

Nor does the size of the material handled seriously affect the results. As has already been stated, the natural sulphides decrepitate when exposed to heat, so that however large the size of the pieces when put into the top of the furnace, by the time they reach the smelting-zone they are in a fine enough condition for smelting. For these reasons ore can be thrown into a pyritic smelting-furnace in any size which will permit of handling in the mine, and its further comminution results as a natural sequence.

Hence, it is not only possible, but economically advisable, in the case of low-grade heavy sulphide ores, to locate a plant as near the deposits as practicable, and to dump the raw ore just as it comes from the mine into the top of the fire-concentrators, and to regulate its smelting by changing the furnace conditions to meet the requirements in each case. The same rules which govern the erection of water-concentrators (which are usually placed at points convenient to the mines so as to avoid the freighting of valueless material) apply in the case of fire-concentrators.

By utilizing the sulphides themselves as smelting fuel, and modern gas-engines as motive power for the blast, etc., it is possible to matte a suitable sulphide ore with an expenditure of less than 4 tons of coal for each 100 tons of ore treated, including fuel for power and for heating the blast. Add to this the labour-saving devices now in use for charging, and removing the waste-products, in furnaces of modern construction—some of the large iron furnaces lately built employ no men at all on top—and it can be readily seen that fire-concentrators may be

operated under favourable conditions at a very low figure, even for less than the usual cost of wet-concentrating, and, as will be shown, with a higher saving of values.

Ores Adapted to Pyritic Smelting.*

The first requisite in an ore to fit it for pyritic smelting is that it should contain enough iron combined with sulphur or arsenic to make an easily fusible slag, and to provide for a matte-fall sufficient to cover the valuable metals contained in the charge.

With regard to fusibility, practice has shown that the best slag for the process is a monosilicate—one in which the oxygen of the silica is equal to that of the bases. To form such a slag requires different amounts of the various bases in common use. For instance, an iron monosilicate calls for 29·41 per cent. of silica to 70·59 per cent. of ferrous oxide; a similar lime silicate requires 34·88 per cent. of silica to 65·12 per cent. of calcium oxide. Substituting magnesia for the lime, we need 42·86 per cent. of silica for 57·14 per cent. of magnesium oxide; and for aluminium, 46·68 per cent. of silica to 53·32 per cent. aluminium oxide, and so on.

Now, to make a ferrous monosilicate slag requires approximately 4 tons of pure pyrites to 1 ton of pure quartz, so we may say that for slagging purposes alone we need an ore-mixture containing 80 per cent. of pyrites and 20 per cent. of silica; but that is using up all the iron on the slag, and does not allow for any matte-fall.

It is a well established fact in smelting that a complex slag, that is to say, one containing a mixture of various bases, is usually more desirable than one consisting of only one base and silica. In other words, a lime-iron slag, or one carrying lime and magnesia, or one containing a number of basic elements, iron, manganese, calcium, magnesium, aluminium, etc., is more easily fused, and possesses other more desirable qualities than simpler slags. Therefore, where it is possible, we aim at making a slag containing several bases.

If the ore-charge be composed of pyrites and quartz in the ratio of 4 to 1, and we add to it limestone, we can form a lime-iron slag, still preserving our monosilicate, and then have iron sulphide in excess which is free to form matte. The addition of lime has another advantage, as it lightens the specific gravity of the slag and renders it more easy to separate from the matte.

* This subject was discussed in the *Mining and Scientific Press*, 1896, vol. lxxii., page 440.

If limestone be not available, we can still form a monosilicate slag and provide for a matte-fall as well, by decreasing the amount of silica or by substituting some other base. In some cases, it is even found desirable to make a more siliceous slag, the iron of the sulphide being prevented from burning to ferrous oxide by slightly altering the furnace conditions.

When an ore is not of the desired composition—that is, when it does not contain 80 per cent. of iron sulphide—other expedients must be resorted to; but it has been found in practical work that an ore-mixture of the composition given will smelt readily without the assistance of carbonaceous fuel in the furnace, and will produce enough matte to effect a saving of 95 per cent. of the valuable metals which it carries.

It is therefore obvious that pyritic smelting finds its limitation in the amount of silica contained in the ore which it is desired to treat, and the question whether or not a given ore is suitable for the process, is one which can be decided by chemical analysis. However, with practice the operator can often determine by simple inspection whether his ore possesses the desired qualifications, but in cases of doubt a silica determination will set the matter at rest. Often simple panning will give all the information necessary. If a few pounds of the ore be ground up, the pulp weighed, and concentrated in a pan, the weight of the resulting sulphides will allow one to make a pretty close guess at the relative amounts of pyrites and quartz in the material under investigation. All that is necessary to be decided is, does the ore contain enough iron in the form of sulphide or arsenide to flux off the silica and form a monosilicate slag? If not, are there other bases available in the neighbourhood to make up the deficiency in iron? Of course, every metallurgist is aware that certain combinations can be made between the various bases which will produce very fusible slags even when a monosilicate is out of the question, so where the case is not as simple as in the ideal proposition discussed above, it is always well to consult an experienced metallurgist. The physical condition of the ores—whether coarse or fine—is not a matter of great importance. There are various cements which can be utilized for cheaply and firmly binding even the finest concentrates into forms suitable for blast-furnace work, and furthermore, with the improved type of pyritic furnace, fines do not interfere with the operation. It must be borne in mind that under any circumstances, no matter how coarse the raw pyrites may be, it decrepitates to fines under the influence of heat, and this fact must be taken into account in handling such ores in the raw state, much depending upon the form of furnace used for the purpose.

The influence of zinc in pyritic smelting is one of considerable importance. The sulphide of zinc (blende) has nearly the same thermal value as the pyrites. Where Mr. Hollway found by calculation, the temperature produced by the combustion of protosulphide of iron to be 2,225° Cent., he estimated in the same manner the temperature resulting from the combustion of zinc sulphide to be 1,992° Cent. So that up to a certain point any blende contained in the sulphide under treatment assists the operation by its heat-producing powers. But there are other qualities possessed by this mineral which render it not so desirable a fuel as iron pyrites. The burning of zinc produces zinc oxide, and the silicate of zinc is not as fusible as that of iron protoxide. However, if the different bases be combined in certain proportions they mingle readily, and in practice, 14 per cent. of zinc in the charge has shown no deleterious results. This is the greatest amount of zinc yet reported in a pyritic smelting-charge, but is not regarded as the limit attainable, and it is probable that a much higher zinc contents can be advantageously used. The zinc oxide, being a base, materially helps out any deficiency in iron, for the zinc is disposed to go into the slag rather than into the matte. Much of this metal is also carried off in the fumes, and in a properly-constructed furnace every opportunity is given to assist its volatilization.

The arsenic, when arsenide of iron is used in the place of sulphide, separates from the iron readily under the influence of a pyritic furnace, and volatilizes, leaving the iron free to unite with oxygen. The results produced from burning arsenide of iron have been almost, if not quite, as good as where iron pyrites was used. The arsenic burns to arsenious acid and goes off in the form of heavy white flakes, which may be caught in suitable dust-chambers. The burning of the arsenic yields also its quota of thermal units to the operation.

According to Mr. Hollway's calculations the temperature produced by the combustion of sulphide of lead is 1,863° Cent., so that any galena present in a pyritic charge is of assistance in producing heat. The lead itself is difficult to save. Some goes into the matte, but a large proportion is either volatilized as sulphate, or is oxidized and goes into the slag, materially assisting in rendering the latter fluid.

Style of Furnace.

In the experimental stages of pyritic smelting, circumstances compelled the use of whatever apparatus was at hand. For this reason blast-furnaces were employed, which had been built originally for other

methods of smelting, and it is largely due to this precedent that furnaces intended for pyritic smelting continue to be built on similar lines, without sufficient consideration being given to the peculiar conditions under which they are to be operated. It appears to be difficult for furnacemen to grasp the idea that for a totally different fuel a different style of apparatus is not only advisable but necessary, and that no matter how well a furnace may be adapted to smelting with coke, when it comes to using pyrites in the place of the first-named combustible a different condition of things has to be reckoned with, and the coke-furnace is no longer suitable. Unless this fact is given due consideration, and the new conditions are carefully studied and provided for, the results are apt to be disappointing. When we hear of experiments being tried with old furnaces, if the results do not come up to anticipations it will usually be found to be due to the fact that the experimenters have not a clear insight into the nature of sulphide fuels, and have attempted the impossible.

That furnaces built on the lines of those intended for lead-ore smelting are not adaptable to pyritic smelting purposes becomes all the more patent, when the two classes of fuel used in the respective processes are considered.

In the first place, coke (which for all practical purposes may be considered as a single element) unites directly with the oxygen of the blast; whereas the sulphides are compounds of sulphur with some other element, and this union must first be broken up before the component elements can unite with oxygen. When the elements of a compound must be dissociated before they are in condition to burn it is evident that a certain amount of preliminary work must necessarily be done, and owing to this preparatory work the sulphides are at a disadvantage in a coke-burning furnace. The result is that where the two fuels—coke and sulphides—are simultaneously operated upon, the coke, which is already in condition to oxidize, is attacked first, and the sulphides are simply melted down and run out of the furnace without being burned to any great extent as long as the coke lasts. This is a partial explanation of the difficulty experienced by experimenters in effecting a proper concentration of the matte, for where the conditions are adverse to the burning of the iron sulphide, it naturally follows that the concentration is poor.

The fact that coke has a much greater exposed surface than that presented by the sulphide-globules, plays also an important part in the selective action of the oxygen of the blast. Coke is a more or less porous mass, and the air penetrates into its innumerable small cells, which

afford the blast a very large surface to operate upon. Pyrites, on the other hand, is a dense metallic substance, which melts in the upper part of the charge, and, losing one atom of sulphur, forms globules of monosulphide equally impervious to the blast. The latter can therefore only work upon the limited surface of these globules, and is restricted in its action as compared with the opportunities presented by the very much larger exposed surface of the coke. So the sulphides are handicapped in an ordinary furnace, firstly, by the necessity of dissociating their elements, and, secondly, by the small extent of the surface that they offer to the blast.

But this is not all: the coke is practically stationary, being held in its place in the charge by surrounding mineral matter until it has been wholly consumed, all the time requisite for the action of the blast being afforded. The monosulphides, however, are in the form of heavy mobile fluids, which rush down through the interstices of the charge, allowing only time for momentary action of the blast. Time is therefore an element of the greatest importance in the combustion of sulphide fuels, for unless the blast is given an opportunity to work on the iron sulphide, little of it will be oxidized, and for this reason also the concentration will be slight.

To sum up, we have in coke a solid, consisting of a single element with a large surface exposed, which is retained in position until consumed: in the sulphides, heavy liquids of very limited surface, requiring dissociation of their elements before the oxygen can act upon them, and which rush through the charge in the briefest possible time. Surely it is unreasonable to expect that an apparatus designed for burning the former class of fuel will be equally efficacious in the case of the latter!

In addition to the behaviour of these two classes of fuel while under the action of the blast, we have also to consider the products of combustion resulting from the two operations. In the case of coke, these are gases—largely combustible gases—which pass upward through the charge, carrying heat with them, and in this upward passage act upon the descending minerals. With sulphides, the products of combustion are principally heavy fluids, which drop downward. The amount of heat carried upward by the sulphurous acid gas and the nitrogen of the air is comparatively small, and may be neglected. When zinc, antimony, arsenic, or lead are present, a volatilization of portions of these elements in their oxide forms will take place, but this is of small moment, and may be overlooked in the discussion of the behaviours of carbonaceous

and sulphide fuels in the blast-furnace. The necessary point to be considered is that in coke-burning furnaces the heat travels upward; in sulphide burners it follows the molten products of combustion downward, necessitating the fortifying of the lower part of the furnace against the intense action of the basic slag and matte.

It is evident, therefore, that in handling these two different combustibles we have got to meet the conditions in each case on wholly different lines if we are to expect satisfactory results.

Firstly, the fusibility of the sulphides precludes the use of high smelting-columns. If we take an ordinary lead-smelting stack, with a distance of 12 or more feet between the plane of the tuyeres and the feed-floor, and charge it up to the doors, we have a smelting-column altogether too high for pyritic smelting purposes. Such a column is necessary for various reasons in lead-ore smelting, and the mass is kept open to a great extent by the fuel burning away so that the blast penetrates to all parts of it; besides, it is desirable that the ascending carbonaceous gases should be given an opportunity to act upon the descending charge and prepare it for the fusion which is to take place in the neighbourhood of the tuyeres, by reducing the ferric to ferrous oxide, driving off moisture and carbonic acid, reducing lead to the metallic state, etc. But in pyritic smelting there should be no carbonaceous fuel to burn away, nor oxides to reduce, and where a high column is used a softening of the sulphides takes place in the upper part of the charge, which adhere to the walls of the furnace and produce a more or less solid mass which the blast cannot penetrate, and which hinders the even descent of the material to be operated upon. For this reason, in pyritic smelting any action of the ascending gases upon the charge is to be avoided if possible.

In pyritic smelting, as there is no necessity for a preparation of the charge before it is brought into a state of fusion, what is wanted is to melt the whole as quickly as possible without permitting a preliminary matting together of its component parts. Therefore, the high smelting-column is a distinct disadvantage, and where it is used, it is also necessary to have more or less coke mixed with the charge to keep it open. With the use of coke, the advantages of the process disappear to a great extent, for apart from the cost of the coke, the two classes of fuel cannot well be used together, for reasons already given.

The best height for a smelting-column in pyritic smelting is one which will present a sufficient resistance to the upward tendency of the

blast to cause the latter to penetrate to the centre of the charge. This, of course, varies with different sizes of furnaces; a wide furnace requiring a deeper charge than a narrow one.

In order to be able to regulate the height of the smelting-column and keep it stationary, recourse is had to an interior feeding-cylinder. This contrivance is so adjusted as to deliver the sulphides at a given point in the furnace-shaft, and at the same time protects them from the action of the escaping gases. In this way, a constant height of smelting-column is maintained and the sulphides are delivered at a point where smelting takes place without permitting an incipient fusion, the heated gases being directed into other channels prepared for them.

Secondly, as the sulphides must first be dissociated before their component elements can combine with oxygen, a considerable amount of heat is absorbed in doing this work. Now, owing largely to the absorption of heat in performing this extra work, if the blast be blown on the sulphides at the ordinary temperature of the air, the extent of surface presented by the globules of molten sulphide is so limited that the heat of combustion is not sufficiently concentrated to fulfil the threefold requirement, of dissociating the iron from the sulphur, bringing the temperature of the oxygen of the blast up to the required point for uniting with the elements thus dissociated, and fusing the next-lying particles which are to be acted upon. The result is that heat from some auxiliary source must be supplied to make up this deficiency, and unless this be done, the globules of sulphide will be blown cold, or, at best, only a roasting process will ensue. In the Manhès process, the air entering the tuyeres is heated by coming into contact with the molten mass, which has already been brought to a high temperature by the preliminary operation of melting the matte in a cupola before charging into the converter. This hot air then attacks the sulphides, and the burning of the sulphur and slagging off of the iron continues as long as there is any sulphide of iron in the vessel, or until the lining of the apparatus gives out. But the converter principle is not applicable to the smelting of low-grade ores because of its intermittent action, and all experiments reported up to the present time where converters have been used for pyritic smelting, have resulted in failure.

In pyritic smelting, as there are no masses of molten matter present from which the blast can take up sufficient heat so as not to chill the small globules of sulphide while acting upon them, it becomes necessary to give the blast this temperature before allowing it to enter the furnace.

There are various ways of accomplishing this. The blast can be heated in a hot-blast stove before entering the tuyeres, or it can be heated in the tuyeres themselves. In the former case, a costly and wasteful apparatus is employed, as the heat passing out through the chimneys, and radiated out through the walls, etc., causes an unnecessary expenditure of fuel for the purpose in hand. If a fire-brick stove be used (and these are the most efficient), its cost may exceed that of the entire balance of the plant: if a pipe-stove be employed, on account of the defects of such an apparatus, only a small portion of the calorific power of the fuel is utilized in heating the air passing through the pipes. By far the best method is to apply the heat (generated usually by gasifying some cheap fuel in a producer) directly to the end in view, by burning it in the tuyeres themselves. One of the advantages gained by applying the heat of the fuel direct to the blast is, that practically all of it may be made available and the expenditure for this purpose is therefore reduced to a minimum. Furthermore, when fuel is burned in the tuyeres, the products of combustion can, if desired, pass into the furnace, and mingling with the heated blast, modify its sharp action. Highly heated air is chemically very energetic, and unless some means be taken to restrain its intensity it is very apt to produce results exceeding those desired, oxidizing the monosulphides, not only to ferrous but even to ferric oxide. For this reason it is best to place it in the power of the furnaceman to be able to modify the action of the blast so as to adapt it to the work to be performed. This is readily brought about by varying the amount of fuel burned in the tuyeres, and allowing the products of this combustion to enter the furnace, in this way rendering the action of the blast intensely oxidizing, neutral, or reducing, at will. This is only possible when heat is applied directly to the blast entering the furnace.

The amount of fuel necessary for the direct heating of the blast is comparatively small, and is readily computed when the calorific power of the fuel, and the volume of the blast, are known. A relatively small amount of inferior fuel burned in the tuyeres is a very much less expensive method of heating the blast, than where a hot blast-stove is used; or where the blast is heated by coke or charcoal burned in the furnace. In any event, where raw sulphides are smelted in a blast-furnace, the blast must be heated in some way, for they will not fuse and produce matte and slag unless an auxiliary source of heat be provided. The prevailing custom (owing to the use of improperly constructed furnaces) is to heat the blast with coke charged into the furnace with the ore; but this is done mostly through ignorance of the true principles involved

in the operation, and often is forced upon the experimenter by an attempt to utilize apparatus already on hand. It is bad practice, and unfair to those who put their money into enterprises of this class.

Thirdly, as the charge column in a properly conducted pyritic smelting-furnace must of necessity be low, and as the heavy globules of molten sulphide drop past the tuyeres very rapidly, it follows that the time during which the blast can act upon them is very short. If, therefore, a weak blast (such a one as is usually employed in lead-smelting operations) be brought to bear upon these quickly-moving globules, its action is comparatively ineffective, and the molten globules escape with only a partial oxidation of their surfaces. For this reason it is necessary to use a higher pressure than that ordinarily employed in western blast-furnace practice. The molten sulphides must be broken up, in fact they must be sprayed and blown against the siliceous portions of the charge (held in suspension as it were) until a sufficient oxidation has taken place.

Care must be exercised that the volume of the blast is not too large, for (as has been shown in practice, and as will be apparent by submitting the matter to analysis by thermal calculations) if even a slight excess of air be blown into the furnace, the cooling effect of the surplus air is very marked. The furnace can even be blown cold by too large a volume of blast. To illustrate the effects of introducing increasing amounts of air into a pyritic smelting-furnace, let us take a formula which gives the maximum efficiency of any fuel burned in a blast-furnace, with a blast heated to 400° Cent., and then successively bring into such a formula increasing amounts of air.

Let $P_n = \frac{\Sigma ag + 0{\cdot}2375\ tq.}{\Sigma pc - c_n} = T$ be such a formula, in which P_n, is the maximum temperature attainable before the tuyeres; a, calorific power of each element; g, weight in pounds of each element; t, temperature to which blast is heated; q, weight in pounds of air necessary for combustion; p, weight of each product of combustion; c, specific heat of each product of combustion; c_n, specific heat of the fuel; and 0·2375, specific heat of air.

Then we have in the case of iron monosulphide, when only the theoretical amount of oxygen necessary for the operation is introduced:—

$$T = \frac{1155 + 0{\cdot}237 \times 400 \times 2{\cdot}3523}{0{\cdot}6683 - 0{\cdot}1357} = 2{,}587° \text{ Cent.}$$

If we now add 50 per cent. of additional air, then

$$T = \frac{1155 + 0{\cdot}237 \times 400 \times 3{\cdot}5289}{0{\cdot}9471 - 0{\cdot}1357} = 1{,}835° \text{ Cent.,}$$

and we see that the temperature is materially lowered.

If double the necessary quantity of air be introduced, then we find the value of T to be:—

$$T = \frac{1155 + 0{\cdot}237 \times 400 \times 4{\cdot}7046}{1{\cdot}2258 - 0{\cdot}1357} = 1{,}469^\circ \text{ Cent.},$$

which is scarcely a smelting temperature, and if three times the requisite amount of air be blown into such a furnace, then we have:—

$$T = \frac{1155 + 0{\cdot}237 \times 400 \times 7{\cdot}0569}{1{\cdot}7833 - 0{\cdot}1357} = 1{,}107^\circ \text{ Cent.},$$

which is equivalent to saying that the furnace will be blown cold. It is, therefore, clear that anyone who has been accustomed—as in lead or copper-smelting—to pump all the air into a furnace that it will take, will (especially if the blast be weak) cool off the sulphides immediately in front of the tuyeres without penetrating the charge far enough to oxidize those lying more towards the centre. The result of such an experiment will be that the experimenter will be obliged to resort to coke, or his furnace will be frozen-up in a very short space of time.

So, what is evidently wanted is pressure of blast, not volume, and therefore the tuyere-openings must be carefully adjusted to the needs of the furnace, so that just sufficient air for the requirements of the operation will pass through the tuyeres, and under sufficient pressure to reach the centre of the charge. When the furnace is properly managed the oxygen entering the tuyeres should be consumed to the extent that sulphur-fumes will distil off from the surface of the charge, and may be collected and further utilized.

Fourthly, to protect the workmen from the stifling gases given off by a pyritic furnace, and at the same time to provide for the regular charging of the ore and fluxes, the top of the furnace should be kept closed and a proper feeding-device provided. Such an apparatus has been designed which is automatic in its action (not requiring the presence of workmen on the top of the stack), and which distributes the various portions of the charge in the parts of the furnace where it is desired to place them. By keeping the easily-fusible sulphides to themselves and protected from the heat of the escaping gases as they descend into the smelting zone, and by placing the infusible portions of the charge so that they can be heated by the escaping gases and will retard the fumes and dust blown off, the working of the furnace is much more regular.

Concentration and Saving.

The degree of concentration effected in a pyritic smelting-furnace is in direct ratio to the amount of iron burned, hence to make a good con-

centration the monosulphide must be retained under the influence of the blast until the desired quantity of iron has been converted into oxide. For reasons already given, a high concentration cannot be expected where coke and sulphides are burned simultaneously, unless the matte is repeatedly passed through the furnace. Where this is done, however, a concentration of 10 into 1 is readily effected.

Where no coke is used there is no reason why any desired degree of concentration should not be reached, but to accomplish this, two smeltings are necessary. Assuming that, in order to make a slag which can be thrown away, a concentration of 5 into 1 is all that can be done with a given ore in a first smelting, then the first matte may be charged back into the same furnace, together with highly siliceous ores, and concentrated 5 into 1 a second time. One ton of the second matte then represents 25 tons of the original ore, and the concentration is therefore 25 into 1. The slag from this second concentration may sometimes contain too much valuable metal to throw away, but in such cases it may be put back into the furnace with a subsequent charge of raw ore, where it is of assistance in keeping the sulphide mass open.

A second treatment of the matte produced in the raw-ore smelting is not usually an additional expense, as would at first appear to be the case. If a furnace be rated at 150 tons of ore per diem of 24 hours, and 5 tons of raw ore are concentrated into 1 ton of matte, there are produced 30 tons of the latter every day, and in 4 days there will have been accumulated 120 tons of matte. Now this amount of matte will require about 30 tons of quartz to slag off the iron and concentrate it further, so if the plant consists of only one furnace, every fifth day can be set aside for matte-concentration. As very siliceous ores are best employed for concentration purposes, and as such ores always command a high smelting charge in the market, this secondary operation may, under favourable conditions, be even more remunerative than the raw-ore smelting itself. As the slag resulting from the concentration of the matte is put back into the raw-ore smelting, there is no danger of losing values from this source, and, therefore, a high-grade siliceous ore may be used for the purpose.

That concentration in a pyritic furnace can be carried to whatever point is desired, is seen when an effort is made to retain the monosulphide in the furnace instead of allowing it to escape as soon as formed. Under such conditions it will be wholly consumed, only slag resulting from the operation. This has been demonstrated repeatedly in an experimental manner, though of course the values contained in the original ore are then found in the slag.

As a usual thing, the further concentration is pushed, the higher will be the slag-assays; but by adopting a system of double smeltings as outlined above, the amount of values going into the slag is of little concern, for they are again recovered in the raw-ore smelting.

The percentage of saving effected in pyritic smelting depends upon several factors, prominent among which are, the composition of the furnace-charge, the amount of matte-fall, and the time given for the separation of the matte from the slag.

With regard to the matte-fall, if the saving of silver values is alone to be considered, a fair concentration may be made in an iron matte, provided the matte-fall is large enough. As this subject has been fully treated in standard metallurgical works (Messrs. Kerl, Percy, Plattner, etc.), it would be mere repetition of what has already been written to go into it here, and those desiring to inform themselves upon this point are referred to the above named authors.

When the aim of the process is to collect gold, an iron matte has not given satisfaction so far, as the affinity between gold and the sulphide of iron does not appear to be sufficiently great to cause a good concentration of the former in a matte composed of the latter. However, it has been found in practical work that if a small amount of copper be present in the charge the collection of the gold in the matte is very good. One per cent. of this metal has been found to give a saving of 95 per cent. of the gold contents of an ore, but 2, or even 3 per cent., are more desirable where they are attainable.

The amount of matte-fall necessary to effect a given saving must be determined experimentally in each instance, for a hard-and-fast rule cannot be laid down which will cover every case. Much depends upon the composition of the furnace-charge, the style of the furnace used, the skill of the man in charge of the operation, etc. A concentration of from 5 to 10 tons of ore into 1 ton of matte in one smelting is not difficult, and by making a double smelting, from 20 to 30 into 1 is attainable. Where copper is the principal valuable ingredient of an ore, the degree of concentration is governed by the richness of the ore, because in pyritic smelting it is not feasible to make a higher grade matte than in ordinary blast-furnace work. As far as reported to date, a 45 to 50 per cent. copper matte is as high as has been made, but this grade of matte is turned out regularly by at least one works. There seems to be, however, no reason why oxidation of the matte should not be continued in a pyritic furnace until white metal is produced, or even to black copper, but as far as known this has not yet been attempted.

There are two methods in vogue for separating matte from slag, some preferring to allow the matte to settle in the crucible of the furnace and to tap off the matte and slag separately; others choosing to let them both flow into an outside "receiver" and there separate. The outside receiver was adopted by copper-smelters to avoid the trouble caused by the formation of "sows" in the crucibles of their furnaces. Where a strongly reducing atmosphere is used in the shaft of a furnace, together with a basic charge, some of the iron is reduced to the metallic state and accumulates in the crucible in such masses as to often interfere with the operation of the furnace. Such an accumulation of metallic iron can even form in matting furnaces, for the monosulphide of iron has the property of dissolving more or less metallic iron at a high heat, which is precipitated at a lower one, so that sows may be built up in this way.

But with pyritic smelting-furnaces there is no danger from this source, as no metallic iron can maintain a separate existence in the oxidizing atmosphere of these furnaces, and so the necessity for a receiver is not apparent. It is well, however, to draw off the slag into a reverberatory furnace and to keep it there for a considerable time before discharging it, in order that any matte which may have become entangled in it shall have ample time to settle out. The values contained in slags, when matte is also present in the furnace, are usually present in the small particles of matte mixed through them, and it has been demonstrated repeatedly that if such slags are kept in a fairly liquid condition for a number of hours, the matte will sink to the bottom and leave the slag very clean. Attempts have been made to throw this entangled matte out of a slag by bringing the latter, while still quite liquid, into a rapidly revolving vessel, when it was found that the matte was thrown to the periphery, leaving the slag with only traces of valuable metals. But so far experimenters with such apparatus have failed to produce a machine which is satisfactory, the mechanical obstacles in the way being very great.

The specific gravity of a slag has much to do with the facility with which it can be separated from the matte, and therefore with the values contained in it. The specific gravity of a pure ferrous silicate is so near that of an iron matte, that the two separate with difficulty unless they are kept very liquid for a long time under conditions favourable to their separating. On the other hand, a complex slag, consisting of a mixture of the silicates of the lighter bases with silicate of ferrous oxide, rises readily from most mattes. Hence it is always advisable to use limerock, or its equivalent, in the furnace-charge when it is economically possible.

When experience has been acquired in the operation of a pyritic fur-

nace, and with the necessary amount of matte-fall, and when time is given the matte to separate from the slag, a saving of from 95 to 98 per cent. of the gold, silver and copper contained in a pyritic ore can be realized in a properly constructed furnace.

Mr. G. B. Reynolds (London) wrote that the interest of Mr. Austin's already interesting paper would be enhanced if he would give some figures showing the composition of the slags made in pyritic smelting. Dr. Carpenter, at Deadwood, used magnesian limestone as the only flux in smelting siliceous gold ores* making presumably a slag such as would be made in an iron blast-furnace. Further, could the author give any information as to the losses by volatilization in pyritic smelting, as it would seem that with the small height of the charge, and the necessarily "hot top," the losses must be large, though recoverable to a certain extent in the flues.

Prof. H. Louis (Newcastle-upon-Tyne) wrote that Mr. Austin's paper on his especial subject of pyritic smelting deserved respectful study, but it would have been of greater value had he given more information concerning the practical execution of the process. It is a curious fact that amongst all the really considerable mass of literature that the last few years have produced on this subject, the majority of the writers, all, too, advocates of pyritic smelting, confine themselves to generalities and omit the facts. It would, for instance, be infinitely more satisfactory if Mr. Austin would favour us with plans and dimensions of the furnaces which he has found most successful in treating a definite kind of ore. He here states that he uses a furnace with an inner cylinder; it has, however, been stated by others that Mr. Austin had some time ago discarded this tube, and it would be interesting to know whether he had reverted to it, and if so, under what conditions. Other pyritic smelters claim that they obtain perfectly satisfactory results without the use of such a tube. Another point of importance upon which information is needed is the result practically obtained by pyritic smelting processes. If Mr. Austin had favoured the members with the actual results of, say, a 12 months' campaign, they would be in a position to judge of the value of the process which he advocates. Perhaps he will kindly give the figures for a 6 months' or 12 months' run, the amount of ore treated, the quantity and nature of the fluxes used, the quantity of coke charged into

* *Engineering and Mining Journal* (New York), 1893, vol. lv., page 28.

the furnace, the quantity and nature of fuel consumed in heating the blast, and in producing the blast, temperature, volume and pressure of air injected, the quantity of matte produced, together with assays of the ore, matte and slag. If the members had such a table before them, they would at any rate be able to judge of the efficiency of the process, and if he would add the annual wages bill and repair account, they could readily arrive at its economic value also. So far, it had been impossible to obtain any records of results obtained over a period of more than a few days, and the doubt, whether true pyritic smelting (that is to say, the smelting of ore absolutely without the addition of any carbonaceous fuel in the furnace) has ever been carried on anywhere continuously for more than a few days is quite justifiable. It is to such an authority as Mr. Austin that members are entitled to look in order to have that doubt set at rest, and until he or someone of equal experience will enlighten members as to the technical and economic results obtained in a lengthy campaign, it will be necessary to look upon pyritic smelting as a subject of theoretical speculation that has not yet emerged from the purely experimental stage.

DISCUSSION ON MR. HALLIMOND'S "NOTES ON THE COAL-SEAMS OF THE TRANSVAAL."*

Mr. Frank Simon (Johannesburg) wrote that Mr. Hallimond stated that duff was useless, but his opinion as to the coking qualities of Middelburg coal would have been useful, as some mines turn out a good coke. Does Mr. Hallimond claim that the appliances at the Rand collieries effect a saving of 1s. per ton in comparison with a similar well equipped colliery in the Transvaal? He (Mr. Simon) understood that Mr. Hallimond claimed a saving of 3½d. per ton in banking-out and tipping, and further, "the saving by the use of distributing-shoots, as adopted at the Rand collieries, is about 8½d. per ton on the present output," which together equal a saving of 1s. per ton. Mr. Hallimond did not state how and in what manner the shoots at the Rand colliery differed from those in use at other collieries, neither did he point out the new features in his method of dumping. A shilling per ton saving in surface-cost is a large item in this or in any other country, and it would be instructive to know how it was effected by a comparison between the costs at the Rand colliery and, say, the Cassel colliery.

The meeting was then closed.

* *Trans. Fed. Inst.*, vol. xiii., page 372.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN THE ROYAL OAK HOTEL, EDWINSTOWE, JUNE 19TH, 1897.

MR. M. H. MILLS, PRESIDENT, IN THE CHAIR.

ALTERATION OF RULES.

The SECRETARY gave notice, on behalf of the Council, for alterations of the Rules, as follows:—

Article 6, Section IV., to read as follows:—

> The *Transactions* of the Institution shall not be forwarded to persons whose subscriptions are in arrear.

Article 2, Section V., the first line and a half to be cancelled, and the following to be substituted in its place:—

> No person shall be nominated for the office of President more than two years consecutively, and at the expiration of such two years he shall not for a period of three years be eligible to be nominated for that office.

The remainder of the article to remain as at present.

The SECRETARY read the balloting-list, prepared by the Council for the election of officers for the year 1897-98; also for the re-election of the present representatives of the Institution upon the Council of The Federated Institution of Mining Engineers for the year 1897-98.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE STEPHENSON MEMORIAL HALL, CHESTERFIELD, AUGUST 28TH, 1897.

MR. M. H. MILLS, PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen :—

MEMBER—

Mr. JOHN BENNETT, Colliery Manager, Langwith Colliery, Mansfield.

ASSOCIATE—

Mr. ALBERT HENRY MEAKIN, Miner, Mansfield Road, Eastwood, Notts.

STUDENTS—

Mr. WILLIAM NOOTT, Mining Student, Haunchwood Collieries, Nuneaton.

Mr. WILLIAM HENRY SANKEY, Mining Student, Tibshelf Colliery, Alfreton.

Mr. ALFRED CHARLES LEPOER TRENCH, Mining Student, Haunchwood Collieries, Nuneaton.

ALTERATIONS OF RULES.

The alterations of which notice was given at the previous General Meeting* were moved by Mr. G. A. LEWIS, seconded by Mr. M. DEACON, and agreed to unanimously.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

Mr. E. EASTWOOD moved that the following gentlemen be re-elected as the representatives of this Institution on the Council of The Federated Institution of Mining Engineers for the ensuing year :—

Mr. E. BAINBRIDGE.	Mr. W. F. HOWARD (*ex-officio*).	Mr. J. A. LONGDEN.
Mr. G. J. BINNS.	Mr. J. JACKSON.	Mr. M. H. MILLS.
Mr. G. E. COKE.	Mr. H. LEWIS.	Mr. W. SPENCER.
Mr. M. DEACON.		

Mr. W. D. HOLFORD seconded the resolution, which was unanimously agreed to.

The Annual Report of the Council was read as follows :—

* *Trans. Fed. Inst.*, vol. xiv., page 132.

ABSTRACT OF ACCOUNTS.

	INCOME.	£ s. d.	£ s. d.
185	Members at £1 11s. 6d.	291 7 6	
	Two Associates and Student paid difference as Members	1 3 0	
1	Associate Member...	1 11 6	
88	Associates and Students	88 0 0	
17	New Members and Entrances	44 12 6	
	Four Entrances from Associates and Students ...	2 2 0	
	One Entrance from New Member of 1897-98	1 1 0	
1	New Associate Member and Entrance	2 12 6	
16	New Associates and Students	16 0 0	
308			448 10 0
	Eight Members paid in advance, 1897-98	12 12 0	
	Two Associates and Students paid in advance, 1897-98	2 0 0	
			14 12 0
			463 2 0
	Arrear Subscriptions received, in List	16 4 6	
	Do. do. not in List	2 18 6	
			19 3 0
	Transactions and Excerpts sold...		3 2 11
	Midland Railway Company's Debenture Interest ...		15 9 4
	Bank Interest		3 10 10
	Total Receipts ...		504 8 1
	Balance from last year		87 9 9
	Unpaid Arrears as per Subscriptions Account ...	55 1 6	
	Do. 1895-96 Account... ... ... £32 8 6		
	Do. 1894-95 do. 4 3 0		
		36 11 6	
		91 13 0	
	Irrecoverable	40 11 0	
			51 2 0
			£642 19 10

Certificate of £533 6s. 8d. Midland Railway Company's 3 per Cent. Debenture Stock, and Policy of Assurance with Alliance Co. for £500, deposited in Bank.

YEAR ENDING JULY 31ST, 1897.

EXPENDITURE.	£ s. d.	£ s. d.
The Federated Institution of Mining Engineers upon copies of *Transactions*, supplied at 17s. per Member:—		
Balance of Calls, 1895-96 (Vols. X. and XI.) ...	1 14 0	
Part of Calls, 1896-97 (Vols. XII. and XIII.) ...	271 9 0	
Transactions supplied on payment of arrears ...	5 1 11	
		278 4 11
Excerpts, Exchanges, etc.		20 12 6
Printing and Stationery, A. Reid & Co., Ld.	21 5 2	
Do. do., Bemrose & Sons, Ld.	20 19 4	
Do. do., W. Edmunds	0 17 2	
		43 1 8
Auditors		3 3 0
Reporting Proceedings		15 10 0
Fire Insurance		0 14 6
Postages, Parcels, and Telegrams		12 16 1
Travelling and Incidental Expenses		17 5 10
Fees at Meetings, Requisites, and Services		2 14 5
Secretary's Salary, Assistance, and Use of Office		100 0 0
Midland Institute of Mining, Civil, and Mechanical Engineers—Joint Meeting		2 14 5
Guests at Tamworth and Dukeries Excursions		3 5 6
Cleaning Portrait of the late Mr. Charles Binns		5 8 6
Bankers' Commission		0 15 3
Total Expenditure ...		506 6 7
Arrear Subscriptions		51 2 0
Balance as per contra		85 11 3
		£642 19 10

August 12th, 1897,
Examined and found correct,
JOHN HALL,
JOHNSON PEARSON, } AUDITORS.

DR. THE TREASURER IN ACCOUNT

		£ s. d.	£ s. d.
222	Members, as per List, 1896-97, of whom		
8	are Old Life Members		
214	Members at £1 11s. 6d.	337 1 0	
	Less 9 paid in advance last year	14 3 6	
			322 17 6
222			
	Eight Members paid in advance, 1897-98	12 12 0	
	One New Member, 1897-98, paid entrance	1 1 0	
	Two Associates and Students paid difference as Members	1 3 0	
			14 16 0
2	Associate Members, as per List		3 3 0
111	Associates and Students, as per List, of whom		
1	Student is a Life Member		
110	Associates and Students at £1		110 0 0
17	New Members and Entrances	44 12 6	
1	New Associate Member and Entrance	2 12 6	
16	New Associates and Students	16 0 0	
34			63 5 0
368			514 1 6
	Arrears per last Balance Sheet	52 16 0	
	Deduct Irrecoverable, not included in 1897-98	40 11 0	
			12 5 0
			£526 6 6

WITH SUBSCRIPTIONS, 1896-7. CR.

		Unpaid. £ s. d.	Paid. £ s. d.
185	Members at £1 11s. 6d.		291 7 6
8	Old Life Members		
9	Paid in advance last year		
20	Unpaid	31 10 0	
222			
	Eight Members paid in advance, 1897-98		12 12 0
	One New Member, 1897-98, paid entrance		1 1 0
	Two Associates and Students paid difference as Members		1 3 0
1	Associate Member, paid		1 11 6
1	Do. retired, unpaid	1 11 6	
2			
88	Associates and Students, paid		88 0 0
22	Do. do. unpaid	22 0 0	
110			
17	New Members and Entrances		44 12 6
1	New Associate Member and Entrance		2 12 6
16	New Associates and Students		16 0 0
34			
368		55 1 6	459 0 0
	Arrears as per last Balance Sheet	36 11 6	16 4 6
		91 13 0	475 4 6
	Irrecoverable	40 11 0	
	Arrears to collect		51 2 0
			£526 6 6

August 12th, 1897.—Examined and found correct,

JOHN HALL,
JOHNSON PEARSON, } AUDITORS.

The PRESIDENT moved the adoption of the Report.

Mr. G. J. BINNS (Netherseal) seconded, and the resolution was carried unanimously.

ELECTION OF OFFICERS—1897-98.

The scrutineers (Messrs. C. J. Oliver and G. C. Leach), who received the thanks of the meeting for their services, reported the result of the ballot as follows :—

PRESIDENT.

Mr. M. H. MILLS.

VICE-PRESIDENTS.

Mr. G. J. BINNS.	Mr. H. R. HEWITT.
Mr. G. E. COKE.	Mr. C. R. MORGAN.
Mr. M. DEACON.	Mr. T. A. SOUTHERN.

COUNCILLORS.

Mr. G. H. ASHWIN.	Mr. J. H. W. LAVERICK.
Mr. A. S. DOUGLAS.	Mr. G. A. LEWIS.
Mr. W. H. HEPPLEWHITE.	Mr. J. B. SMITH.
Mr. C. R. HEWITT.	Mr. H. WALTERS.
Mr. J. P. HOUFTON.	Mr. S. C. WARDELL.
Mr. W. B. M. JACKSON.	Mr. W. WILDE.

PAST-PRESIDENTS (*ex-officio*).

Mr. G. LEWIS.	Mr. A. BARNES.
Mr. J. JACKSON.	Mr. W. SPENCER.
Mr. J. A. LONGDEN.	Mr. E. BAINBRIDGE.
Mr. H. LEWIS.	

VICE-PRESIDENTS OF PREVIOUS YEAR (*ex-officio*).

Mr. G. S. BRAGGE.	Mr. R. THORNEWILL.

TREASURER.

Mr. E. EASTWOOD.

SECRETARY.

Mr. W. F. HOWARD.

The PRESIDENT, in thanking the members for again placing him in the chair as President, said that he had considerable diffidence in accepting the position for another year. He was, however, very anxious that The Federated Institution of Mining Engineers should obtain a royal charter, and he thought that being President for another year might enable him to see this difficult operation carried through. He asked the members to consider well the responsible position which they held as mining engineers and colliery managers in regard to the workmen under their charge. They were in very difficult times ; and, whilst it was their duty to manage the

mines to the best of their ability, they ought, in doing this, to consider that it was not only their duty to regard the advantage of their own collieries, but the advantage of the empire at large. He was in a rather different position from many of them, acting as a general mining engineer, and for the interest of landlords more than lessees, with no direct management of collieries, except in one small matter. He had, therefore, perhaps, the advantage of hearing more than one side of the case, without any direct bias one way or the other, and he could not help feeling that mining engineers should be most careful how they acted with their workmen, and how they advised the owners of collieries. The leaders of the workmen at the present day had an equally difficult task before them. Individually, no doubt, they meant to do the best they could for the men, but they, again, should think more of their country, and less of their position as special pleaders for one party. If owners of collieries and other large works were also to be a little more conciliatory, and do more to teach their men to act more generously to each other, he felt sure they would, with the advance of education on this subject, very seldom see any such disastrous strikes as there had been in the past, and such as appeared looming in the near future.

The following paper, by Mr. William Maurice, on "Electric Blasting," was taken as read :—

ELECTRIC BLASTING.

By WM. MAURICE.

Part I.

Acquaintance with the principles and practice of blasting by electricity, though perhaps only a minor point of knowledge to the mining engineer, is nevertheless one of considerable and increasing importance. From a mining engineer's point of view, the subject bears directly upon the safety of workmen and property, and upon the economical extraction of mineral, whilst the commercial aspect is concerned in the consequent increased or decreased market value of the product.

The practice of electrically igniting blasting-charges has grown so rapidly during recent years as to have become familiar to almost everyone; yet, it must, the writer believes, be conceded that an intimate cognizance of the varied fuzes and appliances wherewith a shot may be fired is not by any means widespread. Experience, moreover, is costly, and applied literature is confined almost exclusively to foreign publications and pamphlets issued in the interests of mercantile concerns. But little has been written in ordinarily available journals, considering the comparatively long period during which electric blasting has been practised; and there does not appear to have been any British attempt at collating the facts of history or stages in the evolution of the art beyond the well-known paper of Sir Frederick Abel, on "Electricity applied to Explosive Purposes," being the record of a lecture delivered before the Institution of Civil Engineers some 14 years ago.

It will therefore be the writer's endeavour in the following pages to sketch the history of electric blasting, mainly in its connexion with coal-mining, to date, and subsequently to place before the members some details of modern practice in mines.

Gunpowder.—Gunpowder having served as a useful blasting agent for many hundreds of years, it is only in the natural order of things that there should be some reluctance to exchange it, with its familiar failings, for others which may not inconceivably develop dangers peculiar to themselves.

It is perfectly wellknown, and occasionally admitted, that, for breaking down a "web" of coal, gunpowder has, as yet, no compeer; but it is not so with the systems of ignition. Of these there may be cited tape, friction, and chemical igniters, and the various types of electrically fired fuze. All these systems possess merit, but unfortunately they are all attended with certain disadvantages in working, and, since safety to life and property is menaced by blasting in coal-mines, it becomes necessary to single out those explosives and those igniters which experience has shown to be the least dangerous.

Electrical exploders and high explosives are credited with possessing the essential elements of safety, and to such an extent is this recognized that during last year nearly ten million detonators were imported into this country.

There is considerable evidence to show that the composition of gunpowder was known in the East for ages before it was heard of in Europe, but, as the time of the discovery of saltpetre is confessedly uncertain, it is probably impossible to ascribe a definite date, or even period, to its invention.

Sir George Staunton,* in his account of the Embassy to the Emperor of China, states that "the knowledge of gunpowder seems to be coeval with that of the most distant historic events. Among the Chinese it has been applied at all times to useful purposes, such as blasting rocks, and removing great obstructions."

If any credence can be placed in Chinese records there is inferential evidence of the use of powder in 618 B.C., during the Taing-Off dynasty.

Many accounts are also given of the very early use of gunpowder in India. Philostratus, in his Life of Appolonius Tyanæus† (written in the first half of the third century of the Christian era), says that "the Oxydracæ (who dwelt between the Hyphasis and the Ganges) repulsed their enemies with storms of lightning and thunder-bolts hurled on them from above."

The use of powder is also implied in one of the Gentoo Laws,‡ which are said to be coeval with Moses,§ and in the Sanscrit, which has so long been a dead language, a word is found answering to gunpowder.

Roger Bacon appears to have been the earliest European writer who described its use and composition. He alludes to the substance in several passages, and in one of his treatises he seems to have mentioned the three

* *Embassy, etc.*, London, 1798, by Sir G. Staunton, vol. ii., page 292.
† Philostratus, *Vit. Apoll.* II., § 33. ‡ Lib. II. c. XIV.
§ Grose, *Military Antiquities*, London, 1800, vol. i.

ingredients of which gunpowder is composed—saltpetre, charcoal, and sulphur, though he hides one of the ingredients, charcoal, under an anagram.

Berthold Schwartz, the Franciscan Monk of Goslar, has by some been thought to have invented gunpowder, but he was posterior to Bacon, as the date assigned to his discovery is about 1320, whereas the celebrated English philosopher died in 1292.

It is not clear in what period gunpowder was first used for blasting in mines. Mr. A. H. Stokes* dates its introduction into English lead-mines from 1575: in Tomlinson's *Cyclopædia of Useful Arts* it is stated to have been first used in Hungarian or German mines in 1620, and to have been introduced into England, at the Ecton (Staffordshire) copper-mines, in the same year by some German miners brought over through the instrumentality of Prince Rupert.†

Noting, however, that cannon were employed in the field by Edward III. as early as 1327, it seems at least possible that powder might have been used in mines during the same period.

Historical Experiments.—But these speculations, however historically interesting, only bear upon the subject of this paper in an introductory sense, for the first electrical machine (the Guericke sulphur ball) did not make its appearance until 1671. It consisted of a ball of sulphur mounted upon a spindle, and rotated by one person, whilst another pressed his dry hands on the sphere; the negative charge thus obtained could be removed and used for experimental purposes. Doubtless, many attempts were made to ignite inflammable substances with sparks from this frictional machine and its immediate successors, but no measure of success was obtained until the opening of the Berlin Academy of Sciences by Frederick the Great in January, 1744. With a spark from a courtier's sword, Ludolf there ignited sulphuric ether, or, to employ the picturesque phrase of Dr. Priestley,‡ "set fire to the ethereal spirit of Frobenius."

In 1745, Dr. Watson, Fellow of the Royal Society, succeeded in igniting gunpowder by means of electric sparks.

Persistent efforts continued to be made by savants, but the electrical firing of gunpowder presented difficulties which rendered ignition uncertain. "Powder requires for its ignition either the close proximity

* "Lead and Lead Mining in Derbyshire," by A. H. Stokes, *Trans. Chest. and Derb. Inst. of Engs.*, vol. viii., page 99.

† *The Coal Question*, by Prof. Jevons, second edition, 1866, page 90.

‡ *History of Electricity*, by Dr. Priestley, 1767, page 73.

of a considerable heated surface, or the continued application of heat for a brief period,"* and it was this time element in the problem which the early scientists overlooked. Sir Charles Wheatstone, in a classical experiment on the duration of an electrostatic spark (measured by means of a revolving mirror), found that its maximum duration did not exceed $\frac{1}{14000}$ second; consequently, the only result of a discharge through a heap of powder was to scatter it violently about.

Dr. Benjamin Franklin, the famous scientist and diplomat, seems to have partially overcome this mechanical action by encasing the powder and crushing those grains coming immediately in the line of discharge. In one of his letters to Sir Peter Collinson,† Dr. Franklin thus describes his method of firing gunpowder by means of electricity:—

> A small cartridge is filled with dry powder which is rammed in tightly enough to crush a few grains, two pointed brass wires are then fixed in it, one at each end, so that their points are not further apart than half an inch at the centre of the cartridge, which is then placed in the circuit of the electrical machine; when the communication is completed, the flame, leaping from the point of one to that of the other, through the powder in the cartridge, fires it instantaneously.

About 36 years later, Dr. Wolff found that ignition could be ensured by retarding the electrostatic spark, which he effected by introducing into the circuit a glass tube, wetted on the outside.

There was no further material progress until some time after the discovery in 1800 by Prof. Volta of the primary battery, but with this inauguration of the reign of voltaic electricity its special applicability to the ignition of blasting-charges was recognized and developed by military officers and scientists in every important commercial country in the world.

An improvement on the historic Volta pile was introduced by Dr. Cruickshank in 1801, but the separate cell battery of Dr. Wollaston may be regarded as the first voltaic apparatus of practical value.

Previous to Dr. Wollaston's improvements, however, it is noted that in 1812 Baron Schelling proposed to blow up mines by "galvanism," as the electric current produced by primary batteries was then termed. He ignited the powder by pieces of charcoal, and invented an "electro-conducting cord" to convey the current to the desired locality.‡

The thermal effect obtained by interposing in the circuit of a voltaic battery a short piece of wire of relatively high electrical resistance was noticed by Mr. Robert Hare (professor of chemistry in the

* "Electricity applied to Explosive Purposes," by Sir Fred. Abel, *Practical Applications of Electricity*, 1882-83, page 114.

† *New Experiments and Observations on Electricity*, June 29th, 1751.

‡ *Journ. Soc. Arts*, 1859, page 598.

University of Pennsylvania), about 1822, though Prof. Trommsdorf had discovered the efficacy of large plates in a battery for producing combustion of thin metallic leaves about 1803.*

Prof. Hare devised a voltaic couple consisting of a sheet of zinc and a sheet of copper separated by narrow strips of cloth; these were then rolled up and suspended on a frame over a trough of acid, into which the rolled plates could be lowered when a current was required. Owing to the large area of the plates and the small space between them, this cell was capable of producing considerable heating effects, thereby becoming known as the Hare deflagrator. Prof. Hare is further stated to have been the first to apply electricity to the explosion of blasting-charges.†

In 1820, Dr. Oersted's important discovery of the influence of a current of electricity flowing along a conductor upon a magnetic needle placed in its vicinity, set the scientific world on a new line of thought, which culminated in Prof. Faraday's observation in the autumn of 1831 of the converse problem, namely, how to obtain electricity from magnetism.

Prof. Faraday's epoch-making discoveries may be summed up in two statements, each independent of the other. One was that the separation of a coiled armature from a permanent magnet produced an electric spark in a divided portion of the coil. The other was that the rotation of a copper disc between the poles of a permanent magnet produced a current of electricity.

From the first of these results sprang in a very short period of time the magneto-machines of Messrs. Henley, Wheatstone, and others, to which further reference will subsequently be made.

Between 1835 and 1840, Sir Charles Pasley, with the co-operation of Messrs. Wheatstone and Daniell, brought the use of electricity in gunpowder firing to a practical issue in Great Britain, whilst in the United States Captain Paris, of Boston, employed the Pasley method of electric blasting to loosen large masses of rock. This engineer gave a highly eulogistic account of the new process, which, he considered, excelled the old in presenting greater security from danger, greater certainty of ignition, greater expedition, greater explosive force with a given amount of powder, and less expense. About 1838, the explosion of blasting-charges by means of an electrically heated coil of wire embedded in gunpowder, is stated to have been practiced by French military engineers.

* *Encycl. Met.*, vol. iv., page 221.

† *Spon's Dict. of Engineering*, vol. i., page 581; see also "Notice of a projected Improvement in Blasting Rocks," *American Journ. Sci.*, series I., vol. xvi., page 372.

In 1842, the Roberts single-fluid voltaic battery, and the method of using it for blasting purposes, was described in *The Practical Mechanic and Engineers' Magazine.** The battery consisted of cast-iron and amalgamated zinc plates, placed in dilute sulphuric acid. The entire apparatus comprised the battery, conducting-wires, cartridges, and a galvanometer for testing the latter. The conducting-wires were "insulated from one another, and twisted so as to form a rope," which connected the battery-poles at one end with a cartridge at the other, the latter having "fine steel balance wire" stretched across its terminals. To use this apparatus, the cartridge was placed in the centre of the powder-charge required to be exploded, and the plates were then lowered into the exciting solution, whereupon the steel wire became red-hot, ignited the priming, and exploded the charge.

Sir Wm. Cubitt and others carried out extensive experiments in the winter of 1842-3 at Dover, preparatory to the removal of the Rounddown Cliff on January 26th, 1843. In this operation, 9¼ tons of gunpowder were disposed in three separate charges, and were fired simultaneously by a large copper and zinc battery arranged on the Wollaston principle. 1,080,000 cubic feet of rock were estimated to have been removed. The successful completion of this bold scheme had the effect of popularizing electric blasting: many accounts being given of its use between 1843 and 1850. For instance, the rock of a quarry near Glasgow was blasted by such means; a submarine rock in the North Esk was similarly removed; excavations were in like manner made in the harbour of Dunbar; Sir I. Brunel employed the same agency on the Cliff works of the South Devon Railway; the Wrekin, in Shropshire, was electro-blasted for road material; and the quarrying of rock near Queensferry was similarly effected.

In the course of construction of Holyhead harbour, 6 tons of powder, divided into several charges, were exploded simultaneously by means of platinum wires heated by a Grove battery. The total quantity of rock stated to have been removed by this blast was 40,000 tons, or 3·33 tons of rock per lb. of explosive.

Sir Wm. (now Lord) Armstrong about this time invented his ingenious hydro-electric machine, which produced electricity by the friction of drops of water issuing at a high velocity through a boxwood nozzle. The apparatus consisted, in the main, of a small internally-fired boiler supported upon four glass legs, and provided with suitable devices for collecting the frictional charge. The Armstrong hydro-electric machine

* 1842, pages 45 to 48.

was used experimentally at Woolwich for blasting in 1857, its power, according to Sir Frederick Abel, far surpassing that of any other instrument experimented with at that time :—

> One hundred fuzes, arranged in simple circuit, were frequently exploded by its means, but the great uncertainty of its action, and the difficulty of employing it in the field did not afford encouragement for continuing experiments with it.*

An account given by the same distinguished expert is interesting as indicating the state of the art of electric blasting in 1843:—

> The conducting wires leading from the battery to the mines . . . . were not insulated, either by means of guttapercha or indiarubber; they were composed of strands of copper-wire, placed side by side, and insulated from each other and from the water by being coated with a mixture of beeswax, pitch, and tallow, and then bound over by means of tape and twine, or rope yarn.

The igniting device in general use during the same period is thus described :—

> In the centre of the charge of gunpowder was placed a so-called burster or fuze, a small box or case of wood, with two short copper wires passing to the interior, and firmly fixed, the enclosed extremities being connected by a short bridge of thin wire, composed of metal of inferior conducting power—iron in the first instance, and afterwards platinum, which was surrounded by very fine-grained powder. The protruding extremities of the copper wire thus arranged were connected with the terminals of the circuit wires by means of binding wire, the connexions being covered by means of insulating wrappings. The heating to redness of the fine wire connexion or bridge (or its fusion in the case of iron wire being used), consequent upon the resistance which it opposed to the current, ignited the fine-grained powder by which it was surrounded, and the charge was thereby exploded.

Whilst these applications of voltaic electricity were progressing in Great Britain, experiments were being carried out in the United States, and in Austria, with improved electrostatic generators and Leyden jars—involving, of course, the construction of the first high-tension fuzes. The difficulty of passing an electrostatic spark through grain powder has been already referred to. Colonel Shaw, an American, had, in 1831, advanced a step in the preparation of fuzes, by employing in them an admixture of fulminate of silver and gunpowder, thereby making the path traversed by the disruptive electric sparks of the exploding machine more readily ignitible.

In the years 1842-43 Profs. Varrentrap, in Brunswick, and Gätzchmann, in Freiberg, fired from eight to twelve charges simultaneously, by means of a frictional machine enclosed in a heated box; and in 1845 Mr. C. Winter, of Vienna, wellknown through his important improve-

* Sir Fred. Abel, *op. cit.*

ments in frictional apparatus, fired a powder charge at a distance of nearly 16,170 feet, with the aid of a sensitive fuze and a Leyden jar. Upon this occasion, the telegraph line between Vienna and Hetzendorff was employed as the conducting medium.*

From this time onward, the development of the true high and low-tension systems of blasting each proceeded concurrently along their own lines: the class of fuze now familiarly called high-tension not being then known.

It will be readily seen that progress could not fail to be retarded by the absence of a reliable insulated wire, for the purpose of making necessary connexions. Prof. Faraday, however, came to the rescue by suggesting, in 1847, the employment of guttapercha; hence this natural product became the first waterproof insulation obtainable.

One next finds that electric blasting was practiced by Mr. Dumas in the north of France in 1851. In that year, a 10 cells Bunsen battery was used in a shaft-sinking at Veyras (Ardèche), the ground being so wet that the ordinary mode of blasting was impracticable. The method employed† was to embed a fine iron wire in the powder-charge, and cause explosion by electrically raising this bridge to incandescence.

It is not clear at what date electric shot-firing was first resorted to in British mines, but Mr. Alan Bagot stated‡ that he had tried all forms of firing machines where electricity was the agent, and he mentioned favourably the Siemens and Gramme magneto-electric apparatus, and the Apps induction-coil. With regard to the latter appliance, he mentions "having had a 4 inches one for 9 years in use in mines, close headings, and drifts."

Electric blasting appears to have been practiced in American collieries from the earliest days of the art. An article on "Shaft-sinking in Pennsylvania,"§ published in 1875, gives the following account of the electrical operations:—

> The electric battery, drilling-machines, and higher explosives are employed. . . . . To use the battery efficiently another method of mining must be employed to that with fuze. With the latter the miner selects a portion or single burden for each hole. With the former, the whole force being exerted at the same time, a series of holes are drilled in such proximity that they may help each other. . . . . The shaft-bottom being flat, and, say, 12 feet wide, three or perhaps four holes at the proper pitch are drilled 6 or 7 feet deep, depending upon the breaking qualities of the rock; one near each rib or side, the

* Sir Fred. Abel, *Ibid.*

† *Annales des Mines*, seventh series, vol. xvi., page 243.

‡ *Accidents in Mines, their Causes and Prevention*, 1878, page 131.

§ *Colliery Guardian*, 1875, vol. xxx., page 47.

other or others equidistant from and between them. Another series of holes is drilled similar to the first, only that their bottoms converge towards, or indeed nearly touch, the bottoms of the first series.

If, when the blast is exploded, the mass of rock instead of being broken into fragments as it usually is, should remain solid, it would resemble a right-triangular prism. This mass having been taken out of the bottom necessarily leaves two benches of solid ground. A series of holes is put in each of these. In a large shaft 20 or 30 holes are sometimes drilled before any are blasted.

The exploders or caps used with ordinary blasting-powder are of wood, those for rendrock, giant-powder, or dynamite are copper. Attached to each are two fine copper wires 4 or 6 feet long, covered with an insulating substance of gum or cotton. Being hollow, the caps are filled with a strong detonating powder.

Inserted into this powder are the ends of two wires placed almost to touch each other. The cap is embedded in the cartridge or loose powder; soft dry brick is used for tamping, care being taken not to cut the wires protruding out of the hole. All the holes being charged, the next object is to connect them together. Two gum-covered wires, from the surface or other safe place, are hung down, one on each side of the shaft; one of the hanging wires is connected with one of the protruding wires of a hole, the other protruding wire with that of the protruding wire of the next hole, and so on. The connexions of all the holes are made, thus leaving one protruding wire, which is connected to the other wire hanging down the shaft side. The two wires running up the side of the shaft are connected with the two knobs of the battery, the crank is turned briskly for fifteen or twenty rounds; it is reversed . . . . about four, when the explosion occurs.

Development of Electric Blasting in Mines.—It will perhaps be instructive at this juncture to take a brief glance at the causes that have influenced, more or less, the development of electrical systems of mine blasting. Of these causes probably the main one is directly traceable to the great number of accidents which have been attributed during the past 50 years, both at home and abroad, to powder and fuze. Many reasons can be adduced for the supercession of powder with tape-fuze ignition in mines, but, unfortunately, it is by no means certain that some of the reasons are not equally applicable to any of the proposed substitutes.

The objections due to (1) the high temperature of combustion, both of gunpowder and fuze; (2) the relative ease with which gunpowder may be ignited; (3) the possibility of hang-fires; and (4) the possibility of the products of combustion of a shot forming an explosive mixture in the atmosphere are wellknown.

Special attention was devoted to the use of powder in mines by the Accidents in Mines Parliamentary Committee of 1854; the collective opinion of H.M. inspectors of mines upon the same subject was sought in 1865, and again in 1876, but in no case was it considered practicable to absolutely prohibit the use of powder underground.

The obvious anomaly of permitting tape-fuze to be ignited and eject its showers of sparks into the air of the mine at the same time that the use of naked lights was forbidden, has been recognized since the date of the earliest mines commission. The Select Committee on the Prevention of Accidents in Mines in 1849 elicited the opinion of a witness* that "the use of lamps and gunpowder was altogether irreconcilable." Similar opinions were again expressed before the committee of 1853.† Accidents continued, however, to occur with such frequency that it was generally felt that some step must be taken to minimize the dangers of blasting.

Mr. Alan Bagot, a witness before the Accidents in Mines Commission of 1879-1886, in his work on the prevention of accidents, already quoted, stated‡ that it was—

> Much to be wished that the legislature would authoritatively lay down when explosives should be used in mines, and with what fuze, and that it should enforce more stringent rules with respect to the use of such explosives by incompetent men.
>
> It is not sufficient that the law should enforce a certain sort of tool in blasting operations, it is now time that some definite instructions were issued with regard to the kind of explosive to be used.

A proposition was made in 1885, by the then Secretary of State "that no shots were to be fired in a colliery within a period of three months after the existence of gas has been there reported, during the time that the workmen are engaged in the mine;" but, needless to say, it was strenuously and effectively opposed. The necessity for change was not lessened by the Accidents in Mines Commission of 1879-1886, previously referred to, who reported §—

> Having been able . . . . to pursue the subject of the application of explosives in coal-mines to such definite issues as to warrant the conclusion that the presence of due regulations for promoting the prevention of accidents from explosions in dry coal-mines, where fire-damp is liable to occur in abundance, or where dust accumulations exist, while fire-damp may at the same time, either locally or generally, pervade the air of a mine, does not necessitate the prohibition of shot-firing in such mines; provided always that it be carried out only with explosives of certain kinds, exploded according to certain prescribed methods, the adoption of which has been demonstrated to secure safety against accidental explosions, and to be unattended with practical difficulties.

Thereafter follows a statement of the facts upon which the above conclusions of H.M. Commissioners were based. Further, it is stated that‖—

* Mr. W. Peace, answer 5,082.

† Mr. D. Swallow, answer 2,908, and Mr. H. Wood, answer 3,817.

‡ Mr. Alan Bagot, *op. cit.*, chap. xii., page 88.

§ *Final Report of H.M. Commissioners appointed to enquire into Accidents in Mines*, 1886, page 60.

‖ *Final Report*, page 61.

The security as regards protection against the dangers arising from fire-damp and coal-dust . . . . is always liable to be diminished as long as the practice is pursued of employing as a means of firing shots a fuze which is ignited either by the application of a lamp flame or of a highly heated wire.

and, after recounting the advantages of electrical firing, it is—

Considered that the combination of arrangements for firing by electricity with the use of the high explosives, either with the water-cartridge or with the moss-and-water tamping, is a matter which should receive the serious attention of managers of mines, where recourse to these new methods of shot-firing is necessary.

Nowadays the majority of mine managers recognize fully the value of electric firing, but no sooner is the practice extended to another pit or seam than they meet, like those who have introduced intended improvements in many other industries, with characteristic working opposition.

If there be insufficient gas made in the mine to afford a logical reason for the change the manager explains, possibly the dangers that exist from the presence of coal-dust. The miner, equally alert, replies that "when he was a lad he used to carry powder in his pockets, and fired huge charges daily in atmospheres so thickly laden with dust that he could scarcely see his candle, and yet never had explosions; then why should there be more danger now?" The nature of the dust and the changed conditions were not considered; "the danger of coal-dust was not really so great in former days, when the mines were small and when they had no steam-haulage, when mines were not, as at present, so deep, and the roads over which the coal was taken were not so long, and where the ventilation which dries the air of the mine was more imperfect. It may be that the danger of coal-dust has been really greater in modern days than formerly, just as it is likely in the future to become greater."*

The opinions of H.M. inspectors of mines on the question of blasting are also to the point. Mr. A. L. Steavenson had, however, relieved the writer of the necessity for citing them here, he having brought them forward in discussion† as arguments in favour of the 1896 Explosives Order, which, in its modified form, is the present culmination of the contest between gunpowder and its rivals in the race for supremacy.

Early Blasting Apparatus.—Almost every variety of appliance capable of producing sufficient electrical energy to explode a fuze has been, at one time or another, employed for blasting in mines. The formerly best

* *First Report of the Royal Commission on Explosions from Coal-dust in Mines*, 1891, Sir Godfrey Lushington, answer 77.

† *Trans. Fed. Inst.*, vol. xiii., pages 23-25.

known types of each class may be considered under the following categories:—(1) Electrostatic exploders; (2) induction exploders; and (3) voltaic exploders.

(1) *Electrostatic Exploders.*—It has been already observed that the first ignition of gunpowder was brought about by the application of electrostatic sparks; the explosion so caused being, however, of a purely experimental nature. The general extent to which frictional machines have played their industrial part has also been briefly indicated, and accordingly, it only remains to be shown in what form and manner they did so.

It is an axiom that the mechanical resistance called friction, that is, the resistance to motion which the surface of one body offers to that of another against which it is rubbed, involves the performance of work. If the rubbing surfaces are exactly alike, the work done in overcoming friction is entirely converted into heat energy, without a trace of electrification; but whenever any difference exists between the rubbing surfaces, a part of the work done goes to produce electrification of both surfaces. If, then, there are two suitable dissimilar bodies, arranged so that one may be caused to rub against the other, the electrostatic energy thereby produced can be collected and utilized for the execution of useful work. This is the principle upon which frictional shot-firing machines produce their electrical energy.

Colonel Moses Shaw, of New York, to whose fuze reference has already been made, used a frictional battery for exploding blasting-charges, but there were no specially important developments in this branch of the art until the year 1850.

An eminent Austrian military engineer, Baron von Ebner, with other officers,* then designed a portable glass-plate frictional machine, which proved, however, of little practical value, owing to its extreme susceptibility to damp. Baron von Ebner eventually replaced the revolving glass-disc of the original machine by one made of ebonite, and this alteration resulted in the production of a very servicable appliance. The Von Ebner apparatus has been remodelled from time to time, but the pattern designed in 1874 appears to be still employed by the military authorities of Austria.

* An interesting account of the studies of this military committee is recorded in *Geschichte der Elektrischen Zündung im k. u. k. Oesterreichischen Heere*, by Mr. Kostersitz and others.

Various forms of frictional machine, as used in Europe and the United States, principally between the years 1865 and 1885, are illustrated in Figs. 1 to 6 inclusive (Plate IV.).

Figs. 1 and 2 show the Ladd plate machine, which consists of a teak box containing an ebonite disc 12 inches in diameter, mounted upon a spindle to which a rotative handle is directly coupled. The frictional pad *P* is of leather, coated with mercury amalgam, *S* being a piece of oiled silk attached to the pad. The collector *C* is a brass fork having serrated edges, which latter almost touch the disc. The condenser—which is a kind of storehouse for electrostatic strain-energy—is, in this instrument, composed of tinfoil sheets alternating with similar sized layers of a suitable dielectric, and is placed in the bottom of the containing case.

In Figs. 3 and 4 (Plate IV.) are seen longitudinal and transverse sections of an American design, known as the Mowbray powder-keg exploder. A cask, *A*, with handle and standards, has a head, *B*, resting upon a shoulder cut in the staves, and a bottom, *C*, carrying a test-gauge and discharging sockets. A hard rubber exciting cylinder, *I*, mounted on an insulating spindle, *J*, is surrounded by a vulcanite shield, *a*, carrying the rubber *F*. Two discs, *ff'*, close the ends of the shield *a*, their movement being restricted to one-sixth of the circumference by a slot and pins. Outside this oscillating cylindrical frame is placed a condenser, built up generally as in that previously described. Attached to the inner surface of the cask is a silk cushion, *V*, packed with a mixture of freshly-burnt quicklime and dry mica scales. These last, being dry and feathery, allow space for increase in bulk as the lime slaked, without risk of bursting the envelope. By this device, the air within the case was rendered and maintained sufficiently dry for exciting, collecting, and storing the frictional electricity developed, independent of the state of the outside atmosphere. The mode of operating the machine was as follows:—A crank inserted in *K* was turned clockwise through 60 degrees, the friction between the cylinder and the rubber moving the rubber forward until the end of the slot in the discs *ff'* struck against the collector-rod *G*. The position of the various knobs would then be as shown in Fig. 4, namely, the rubber knob *R* abuts on the dielectric-knob *Q*, and the collector-knob *R'*, on the concave side of the shield *a'*, abuts on the collector-knob *Q'*. By continuing the revolutions the positive charge from the rubber *F* passes by the knobs *R* and *Q* to the concave side of the dielectric, *D*, and this being in permanent connexion with the convex surface of the dielectric *E*, the two surfaces are charged simultaneously. When a sufficient

charge of electricity was accumulated on the several surfaces, a slight reverse movement of the crank moved the rubber-frame and shields $a a'$ backward, the effect being that the knob R of the shield a left the knob Q on the rubber-side, and on the collector-side R^1 left the collector, R^2 left the dielectric knob Q, so that the condenser was charged, insulated, and ready to fire. If the terminals, that is the points in the fuze-head attached to the wires in the sockets W and X, were within striking distance, discharge would ensue on reversing the handle another 30 degrees. The weight of this exploder was about 26 lbs.

The H. J. Smith exploder was introduced contemporaneously with the Mowbray, and with some minor exceptions it is identical with the Ladd machine.

In Germany, Austria, and elsewhere on the Continent of Europe, the Bornhardt exploder was, and still is to some extent, used in mines. An early double-plate pattern is illustrated in Figs. 5 and 6 (Plate IV.). It consists of a zinc-lined wooden box containing as rubbed bodies ebonite discs, as rubbers pieces of cat-skin, and as collectors of electricity two glass Leyden jars. A carrying handle H is screwed upon the top of the box, and one end is suitably pierced for terminals TT', and firing key F. The two latter holes are furnished with stuffing-boxes to exclude damp air, which would immediately arrest the generation of electricity. The discs DD' are about 12 inches in diameter and $\frac{3}{16}$ inch thick, and are rotated through gearing G contained in the side of the case. The friction caused by these discs rubbing against the pads PP' produces electricity, which is collected by platinum points connected with the interior of the Leyden jars LL'. The outer coating of the jars and also the rubbing-pads, are in connexion with the zinc-lining of the case, and therefore, on contact being made by means of the lever N, the discharge will take place through the line wires connected to TT', or through the testing-scale S (Fig. 6), provided that the chains are suitably placed. The scale consists of 16 brass studs, so arranged as to permit a spark to leap from one to the other, and the number of turns required to give this effect is a test of the condition of the machine. The actual operation of firing by means of one of these exploders consists of, first, testing the machine, next, attaching the leading wires, then rotating the handle the required number of turns. A sustained push of the key F will discharge the condenser and fire the fuze. A small packet of chloride of calcium is usually kept in each case, in order to absorb moisture. A double-plate Bornhardt machine in a box 21 inches by 10½ inches by 15 inches weighs about 42 lbs., whilst one containing a single plate and Leyden jar weighs 22 lbs.

The Bornhardt and Ladd machines were used underground by the Chinese Engineering and Mining Company, of Kaiping,* from 1878 onwards, and appear to have given considerable satisfaction. A Bornhardt machine was also used in the St. Vincent shaft-sinking at Montchanin in 1878. With compressed gunpowder and Austrian fuzes, 3,798 blasts were there fired without a single missed shot.

Other exploders, designed by Messrs. Abegg, Mahler, Nobel, etc., being identical in principle, and differing only in details from those already described, need only be mentioned as items of historical interest.†

Influence machines belong to a distinct class of frictional apparatus, which have however only been employed underground to a very limited extent, and do not therefore call for special consideration.

Frictional exploders, notwithstanding their practicability in hot, dry climates, must necessarily give way before the greatly improved magneto-machines and primary cells now available. Apart from the great disadvantages of bulk and weight, they require frequent attention, are easily deranged, and are exceedingly liable to fail altogether if exposed long to a humid atmosphere. This last objection obviously precludes their application in mines where water-spraying is practised, even were they otherwise suitable.

(2) *Induction Apparatus.*—This class is susceptible of subdivision into: (*a*) current-induction exploders, and (*b*) magneto-induction exploders.

(*a*) *Current-induction Exploders.*—If two independent coils of wire be placed in juxtaposition, and an electric current be set up in one of them, a momentary electric pressure is produced in the other one: the electromotive force remaining in the second coil just so long as there continues to be a variation in the intensity of the primary current. In the apparatus known as an induction-coil, this property is utilized by supplying a current to an inducing, or as it is called, primary coil, through a device which rapidly makes and breaks the circuit, thus causing those rapid variations in the current, which are essential to the production of a difference of potential in the induced, or secondary coil.

* "Electric Blasting in China," by Mr. C. W. Kinder, *Proc. Inst. C.E.*, vol. lxxx., page 188 *et seq.* The illustrations of the Bornhardt, Siemens, and Ladd machines have been reproduced, by permission, from this paper.

† Detailed information can be found in "Elektrische Zündung mit Rücksicht auf ihre Verwendung in Schlagwetter führenden Gruben," by Mr. J. von Lauer, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, vol. xliv., page 599.

Considerable variety is exhibited in the construction of induction-coils, but all of them consist essentially of a hollow cylinder, in which is placed a bundle of iron wires, with two helices coiled round it, one connected with the terminals of a battery, the current of which is alternately opened and closed as already indicated, and the other serving for the development of the induced current. Generally, the primary winding consists of a few turns of comparatively thick wire, whilst the secondary coil consists of very fine wire of great length. The practical effect of this arrangement is, that a current of fair volume but low electromotive force passing into the apparatus is there transformed into one of extremely low volume but very high electromotive force; this, when sent over a line containing a high-tension fuze, sparks across the air-gap between the terminal wires contained in the fuze-head, and ignites the priming composition.

It was about 1851 that current induction coils were first rendered available for the explosion of blasting charges. In that year, Mr. Ruhmkorff, a wellknown instrument maker, profiting by the experiences of previous investigators, notably Messrs. Bréguet and Masson, designed a form of apparatus the general principles of which appear in the familiar Ruhmkorff coil of the present day.

The first series of blasting experiments with the Ruhmkorff coil were made at Mr. Herkmann's wire-works, La Villette, Paris, in 1853. Colonel Verdu, a Spanish engineer, who did much to develop electric blasting, conducting the operations. Single charges were successfully exploded through various lengths of wire up to 16 miles, with a coil taking its current from two Bunsen cells. Colonel Verdu also carried out some notable experiments at Guadalaxara, and read a paper on blasting by means of induced currents, before the Paris Académie des Sciences in 1853; whilst Messrs. Southby and Ward occupied themselves with similar trials in this country.

Perhaps the best known example of blasting on a large scale with the Ruhmkorff apparatus is that of Cherbourg, where, during the construction of the harbour, in 1854, six charges, exploded simultaneously, demolished 1,755,000 cubic feet of rock.

In 1855, Mr. E. O. W. Whitehouse took out a patent* wherein a claim is made for—

> The application and use of induction coils, in which the secondary current is generated by reversing the polarity of the iron by the primary current . . . . for . . . . blasting . . . .

* *British Patent Specification*, 1855, No. 2,617.

In 1862, an ingenious but complicated apparatus was designed by Mr. Alphonse Dumas, of Privas, France, and patented in England by Mr. W. E. Gedge* in the first instance and afterwards by Mr. R. A. Brooman.† The following excerpt from the later specification sufficiently indicates the scheme and proposed scope of the invention:—

The apparatus is composed of a generator of electricity, of an induction coil, of a lighting or fluorescent tube, and of a bag or envelope containing the generator and the coil. The generator consists of a single element of a cylindrical battery with two concentric compartments. The outer compartment contains a zinc cylinder, and the inner, consisting of a porous vase, receives a platinum or carbon plate. The parts of this portable apparatus, as the generator and coil, are juxtaposed and fixed in a leather box with wooden bottom and cover. The lighting tube may be carried in the hand or strapped to the bag. Upon the cover of the box there is a button for turning a threaded rod, which on being turned allows of the current from the battery to the coil being closed. On the front, and under the cover, are the two poles of the induced current terminating in union collars. These union collars serve to put the coil in connexion with the lamp, or with wires for exploding charges in mines. . . . On the outside of the box are the wires from the carbon and zinc poles of the battery. These wires allow of the direct current from the battery being used for firing charges in mines, or for the transmission of telegraphic signals. The apparatus may be carried by a man at his side, suspended from a strap over the shoulder.

Comte du Moncel, who gave expert advice in connexion with the blasting at Cherbourg, appears to have been highly satisfied with induced current blasting apparatus, for he wrote in 1857:—‡

Since these experiences, which seem to indicate in the near future the complete solution of the problem of firing mines, physicists, engineer officers, and instrument makers have effected improvements in detail, and the combined result of all their work is a complete set of systems, which provide from to-day means of applying electricity to mines in any cases which may present themselves.

Mr. Alfred Apps and others have done much to bring current induction coils to a high state of perfection; but, notwithstanding the attention devoted to the subject, these instruments have never been employed to any great extent in underground blasting operations, owing, doubtless, to the bulk and weight of the complete apparatus, and the inconvenience resulting from the necessary use of primary batteries.

(*b*) *Magneto-Induction Exploders.*—The earliest known reference to magneto-electricity is to be found in *The Monthly Magazine* for April, 1802. This periodical states that at Vienna it was discovered that "an artificial magnet" decomposed water as well as the voltaic pile. The principles of magneto-induction were not, however, made known until Prof. Faraday announced the results of his investigations in 1831.

* *British Patent Specification*, 1862, No. 1,043. † *Ibid.*, 1864, No. 2,100.

‡ *Exposé des Applications de l'Électricité*, by Comte du Moncel, second edition, page 291.

Magneto and dynamo machines date their introduction from the same year, and it is found that Sir C. Wheatstone was, in 1856, the first person to use this type of apparatus for blasting : a magneto-exploder designed by Mr. Henley being employed in these experiments.

Shortly afterwards, Sir C. Wheatstone introduced some modifications in design, followed by others, such as Messrs. Siemens and Halske, of Berlin, Mr. Bréguet, of Paris, and Mr. Markus, of Vienna, whose machines differed only in detail from those first introduced. The Bréguet *coup-de-poing* exploder is still used in the Borinage (Belgium) and North of France coal-fields.

There are, broadly, three different types of magneto-exploders :—(1) In which current is induced in coils of wire surrounding the poles of a permanent magnet, by suddenly detaching therefrom a soft-iron armature. (2) In which a coil-wound armature is rotated between the poles of a permanent magnet. (3) In which a coil-wound armature is rotated between the poles of an electro-magnet, as in an ordinary dynamo.

Type (1).—The Hickley, Bréguet, and Scola exploders may be taken as examples of this class. The first named machine was introduced by Mr. A. S. Hickley in 1877, and is illustrated in Figs. 7 and 8 (Plate IV.). The several parts are arranged as follows :—To each pole of a compound permanent magnet, *M*, is attached one end of a small bar of soft-iron, *E*, the other end having riveted thereto a vertical rod of the same material, which acts as a core to a reel, *C*, of insulated wire. This core, passing through the centre of each reel, projects slightly above the top. A soft-iron armature, *A*, resting upon the tops of the two vertical rods is fastened to one end of a lever, *L*, the other end of which can be depressed by means of a plunger, *R*. When so depressed, the lever turns on the pivot, *B*, and raises the armature off the tops of the vertical rods; thus inducing an electric current in the magnet-coils, and consequently in the shot-firing line connected therewith.

The Bréguet *coup-de-poing* exploder, whilst identical in principle with the Hickley, is modified in details by various makers. For instance, one firm makes the machine with a plain horse-shoe magnet, another builds up a compound magnet, a third employs the Jamin magnet, which is composed of about 20 strips of spring steel bent into horse-shoe shape and retained in that position by suitable clamps.

The pattern illustrated in Figs. 9 and 10 (Plate IV.) represents the Bréguet exploder in its latest form. A compound magnet, *M*, is placed horizontally upon a hardwood base. From the poles, Ducretet laminated polar extensions of soft-iron project outwards in order to

receive two reels of insulated wire *CC*. Against the pole-pieces presses an armature, *A*, which is fixed upon a lever *L*, turning about an horizontal axis. When the lever is pressed down by a blow upon the knob, *R*, the armature is withdrawn from the coils, and the induced current thus produced is transmitted to the line wires attached to terminals, *SS'*. When the knob, *R*, is released, a spring beneath the lever, aided by the attraction of the magnet, forces the armature back into contact with the poles. A safety-bolt is pushed under the lever to prevent accidental discharges.

Three sizes of Bréguet exploder are made:—(1) The *petit exploseur*, which weighs about 6½ lbs., and fires two detonators; (2) The *exploseur ordinaire*, weighing about 18 lbs., and capable of firing eight caps; and, lastly, (3) the *grand modèle* of 22 lbs. weight, and 12 shots, in series, capacity. The coil-resistance of No. 2 is 6,000 ohms, and 12,000 to 15,000 ohms for the *grand modèle*. In applying these machines, it is usual to have a single insulated line wire and earth return.

The Scola exploder (Fig. 11, Plate IV.) is composed, as in the preceding ones, of a magnet with soft-iron armature and induction-reel. Its action will be seen by comparing the letters of reference with those in the foregoing descriptions. The smallest size is contained in a case measuring 6 inches by 4 inches by 1½ inches, and weighs less than 3 lbs.

Types (2 and 3) include all modern magneto exploders, the best known of which it is intended to deal with in a later contribution. One or two machines not yet mentioned, such as the Siemens and Burgin, may, however, be briefly considered.

The machines referred to belong to type (3), *i.e.*, the dynamo class of exploder, which originated with Messrs. Siemens and Halske, of Berlin.

It has been found practically necessary to construct dynamo exploders on the series method of winding, that is, the field-magnet coils, armature, and external circuit (which in this case is the firing-line) are joined together in series, as though they were so many lengths of jig-rope coupled or spliced end to end.

The general principle upon which all series-wound dynamo exploders work is as follows:—An armature, rotated between the poles of an electro-magnet, has set up in its coils a feeble electric current, due to the magnetization produced by the residual magnetism in the iron. By continuing rotation (with the firing-line short-circuited) the weak current thus started passes round the field-magnet coils, increases the intensity of the field, and, consequently, the volume of current in the armature. This gradual increase or building up of the current goes on until the

maximum capacity of the machine is reached. At the limit of magnetic saturation, the short circuit previously existing is automatically broken, and the whole available energy is switched on to the firing-line.

A Siemens exploder, consisting of a small dynamo with Siemens armature, enclosed in a strongly-made wooden box, measuring 12 inches by 11 inches by 8 inches, is shown in Fig. 12 (Plate IV.). A toothed wheel mounted on a spindle, to which a cranked handle is attached, transmits motion to the armature through a pinion keyed on to the armature shaft. A peculiar cam motion, *K*, on the left-hand side of the figure, short-circuits the dynamo during excitation. After every two revolutions of the driving spindle, a tooth in a specially arranged lever, not shown in the side elevation of the machine, falls into a notch in the cam; this action releases a spring and causes it to come in contact with the set-screw figured below *K*, in the drawing, thus breaking the short-circuit, hitherto existing in the instrument, and permitting the current to pass by the terminals, to which the leading-wires are attached, through the distant fuzes and back by the return wire or earth to the dynamo.

The Siemens low-tension exploder is similar in construction to that already described, but the coils are wound with fewer convolutions of wire, and the latter is of a larger gauge. The electric current is, after a few turns of the handle, sent into the leading-wires by pressing down a firing-key at the top of the instrument. The current then passes continuously into the line until it is sufficiently powerful to heat the bridge-wire of the fuze and cause ignition of the priming. These low-tension exploders are also made with an automatic firing-lever, similar to that in the high-tension machines, in place of the above-mentioned firing-key.

The following table gives the leading dimensions, weight, and capacity of Siemens dynamo-exploders :—

TABLE I.—SIEMENS DYNAMO EXPLODERS.

Type of Exploder.	Dimensions.		Weight.		Average No. of Fuzes Machine will Fire.
	Inches.	Millimetres.	Lbs.	Kilos	
H-T. No. 1	15 × 15 × 7	381 × 381 × 178	59	27	50 high-tension in series.
H-T. No. 2	11½ × 11½ × 7	292 × 292 × 178	28½	13	30 ,, ,,
H-T. No. 3	12 × 11 × 8	305 × 279 × 203	31	14	30 ,, ,,
L-T. No. 1	11½ × 11½ × 7	292 × 292 × 178	28½	13	28 low-tension in series.
L-T. No. 2	12 × 11 × 8	305 × 279 × 203	31	14	28 ,, ,,

The maximum total resistance of the leading-wires (main and return) should not exceed 11 ohms, in order to secure the firing of the number of fuzes referred to against each machine in Table I.

An American dynamo exploder, called the Crescent, was introduced into England some years ago by the Ingersoll-Sergeant Drill Company. It differed from that already described, mainly in its driving mechanism, which consisted of a segmental rack, gearing into a pinion on the armature-shaft, and a coil-spring. To fire a shot, the usual line connexions were made, with suitable terminals, and the machine held firmly whilst a lever handle was turned through an angle of about 45 degrees against the pressure of the spring. At the end of this movement, a trip device released the handle, and the coil-spring, in regaining its normal position, caused rapid rotation of the armature, thereby transmitting the required electric current to the fuze-circuit.

The Bürgin exploder, also of the dynamo class, was at one time extensively used by the Swiss army for rock-blasting and other applications of that nature. The writer is unaware of its ever having been applied to the ignition of shots in coal-mines. It was carried in a case measuring about 12 inches by 10 inches by 10 inches and weighed over 40 pounds. A detailed description of this machine was given by Mr. C. Hirgel Gysi in 1877.*

It may here be observed that, while dynamo-exploders may with advantage be employed in extensive tunnelling operations, etc., they have been designed primarily for military and naval mining services. For these purposes they are enclosed in extra stout cases, in order to stand the excessive strain of rough transport.

(8) *Voltaic Exploders.*—Voltaic exploders, otherwise primary batteries, are appliances for obtaining an electric current by means of the energy of chemical reaction, and they all consist, essentially, of two dissimilar metals in contact with a chemically compound liquid conductor of electricity, or an equivalent combination.

Some of the cells used in early days have been already indicated. One not yet named, the Silvertown pattern Leclanché battery was employed to a considerable extent in the Wigan district about 20 years ago. With this exception it would appear that "wet" primary cells, in contradistinction to those of the pasty or semi-fluid type, have only found tentative application for blasting in collieries.

* *Die Elektro-dynamische Maschine und der Minenzündapparat des Ingenieur Emil Bürgin, von Basel*, by Mr. C. Hirgel Gysi, Zurich, 1877.

Fig. 5.

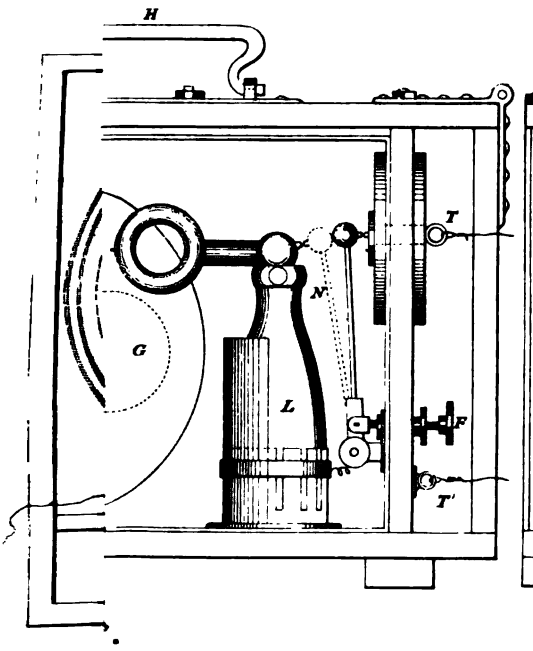


Fig. 6.

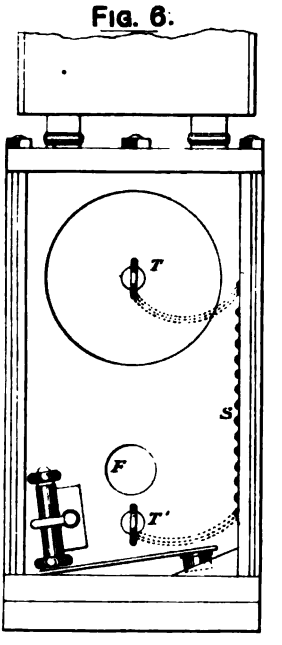
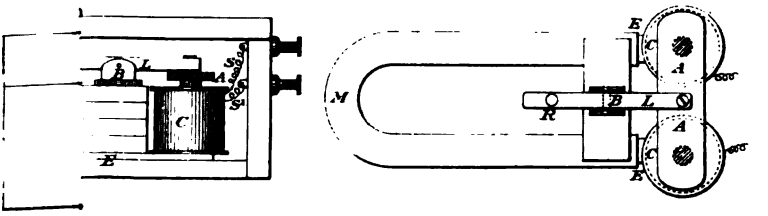


Fig. 8.



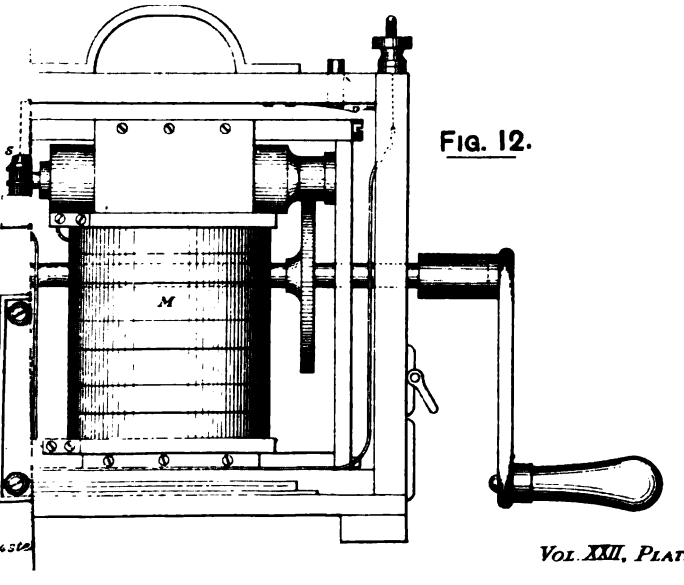


Fig. 12.

Chester

On the Continent, however, they obtained a firmer hold, and have not even yet fallen entirely into disuse. In Austria, for example, blasting operations are still conducted with a Puddot potassium-chromate battery, consisting of four small zinc-carbon elements in a solution of potassium bisulphate and potassium chloro-chromate. Consideration of so called dry cells, coming as it does within the scope of modern practice, must be reserved for a subsequent contribution.

In concluding this part of his subject, the writer desires to acknowledge the kindly assistance which he has received, in his search for historical information, from Sir Frederick Abel, Bart., Dr. C. Le Neve Foster, and Mr. A. H. Stokes, and he has great pleasure in submitting his sincere thanks to them.

The following paper, by Mr. James Mein, on "The Walker Hollow Needle for Firing High Explosives," was taken as read :—

THE WALKER HOLLOW NEEDLE FOR FIRING HIGH EXPLOSIVES.

By J. MEIN.

The primary object of the Walker hollow needle is to avoid the danger incident to the ramming of shots when the detonator and charge of high explosives are placed together in the shot-hole. In the existing method, the detonator is placed in the explosive-charge, and after both are placed in the hole, the ramming is proceeded with. By the Walker method, it is intended to place the charge in the shot-hole, complete the ramming, and, when this is done, the detonator is placed in position. It is obvious under such conditions that it will be impossible for a workman (either by undue violence in ramming or by accident) to fire the charge.

The tools to be used and the manner of using them may be described as follows:—

The hollow brass or copper needle (Fig. 1, Plate V.) is provided with a handle *a*, and is of sufficient length to suit any hole. The outside diameter of the needle is $\frac{1}{2}$ inch, and the internal diameter of the tube along its whole length is $\frac{3}{8}$ inch. At the end, *b*, the needle is slightly reduced in diameter, so as to admit of its being inserted into a paper tube 6 inches in length and of the same diameter as the needle.

The paper tube (Fig. 2, Plate V.) is fixed in the charge, preferably in the process of manufacture, but not necessarily so, and forms a chamber for the reception of the detonator.

A plain copper rod (Fig. 3, Plate V.) is used to push the detonator along the tube in the needle to its position in the charge of explosive; and as an additional precaution, this rod is provided with a paper tip, *c*. The detonator is held in position by a simple spring made of cane or some similar material. Fig. 2 shows the paper tube and the spring *dd*. Fig. 4 is a sketch in section of the charge with the paper tube and the detonator in position, ready for the firing of the shot. Fig. 5 is a complete sketch of the several parts, showing the paper tube *ee*, a portion of the needle *ff*, the copper rod *gg*, and the detonator *h* placed in position.

To illustrate Mr. J. Mein's Paper on "The Walker Hollow Needle for Firing High Explosives." Vol. XIV Plate V

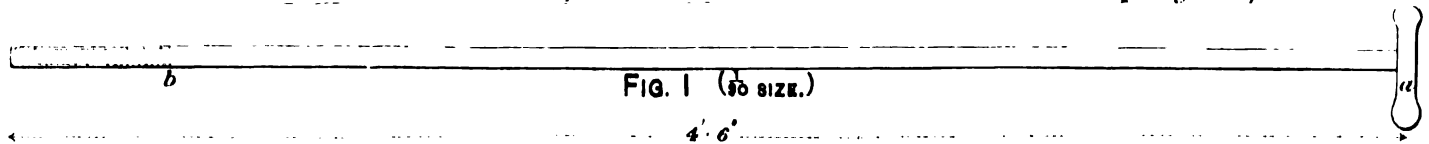


FIG. 1 ($\frac{1}{30}$ SIZE.)

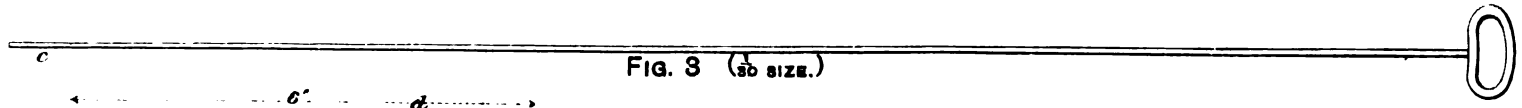


FIG. 3 ($\frac{1}{30}$ SIZE.)

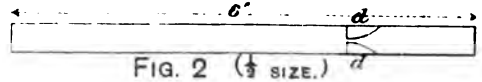


FIG. 2 ($\frac{1}{2}$ SIZE.)

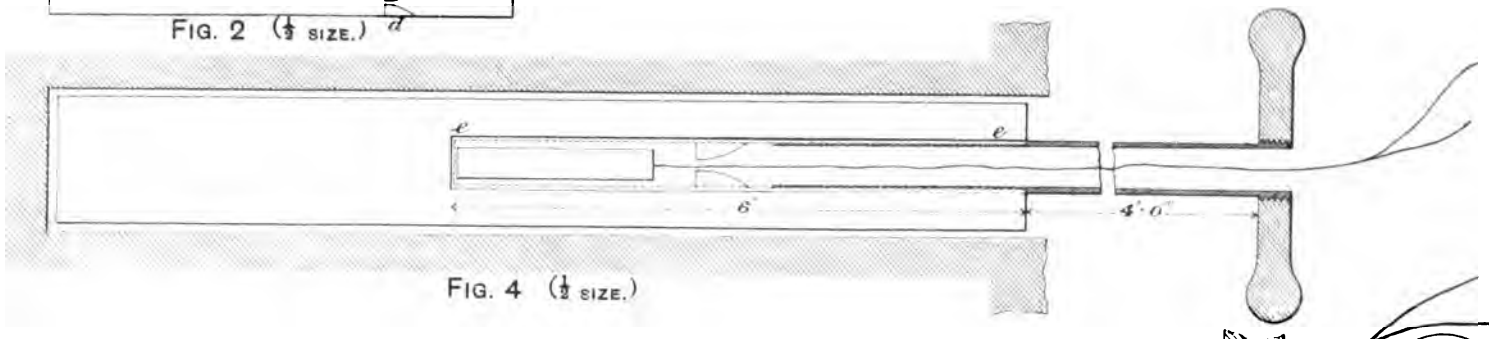


FIG. 4 ($\frac{1}{2}$ SIZE.)

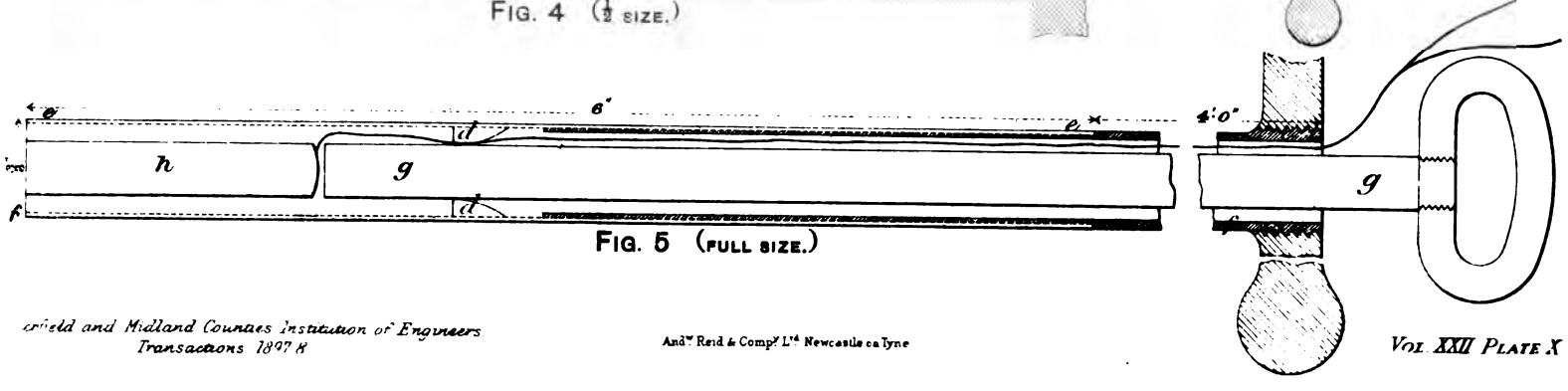


FIG. 5 (FULL SIZE.)

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And.w Reid & Comp.y L.td Newcastle on Tyne

Vol. XXII Plate X

The complete operation of preparing a charge for firing may be described as follows:—

The paper tube *ee* (Fig. 5, Plate V.) being fixed in the charge, the hollow needle *ff* is inserted therein, and the charge is then placed by means of the needle in position in the shot-hole. The ramming is then made, after which the detonator is placed in position by being pushed along the hollow needle by means of the copper rod.

The detonator being now in position and secured by the springs *dd*, the copper rod and needle are simultaneously withdrawn, and the shot fired by electricity in the usual way.

By the adoption of the above-described method, the desired end of effectually separating the charge of explosive and the detonator during the dangerous operation of ramming, and of isolating the two dangerous elements as long as possible, can be better effected than at present, because the stall-man or other workman requiring a shot to be fired, has in his keeping the blasting-material only (which admittedly, of itself, is perfectly harmless). While on the other hand, the detonators are wholly in the keeping of the shot-firer, who is a reliable official; and until the final operation of firing the shot, it is not necessary to bring the explosive and the detonator together. The total additional cost incurred by the use of this arrangement will not exceed ½d. per shot.

Mr. A. H. Stokes said that the author appeared to be under the impression that, with high explosives, hard ramming was required, such as might cause the firing of the detonator; but such ramming would be against all rule, for ramming must be very light indeed where high explosives were used. He observed that, when placing the detonator in position, it was pushed into its place by passing through cane springs. In being pushed past the springs, were they likely to fire the detonator by friction? and, further, in pushing the detonator down, there might be danger by pulling the wires out of the cap. During the last month, two men were sent to the Chesterfield hospital, who had their fingers taken off by explosions of detonators. There had been a miss-shot, and the men in each case were trying to ascertain the cause, and, strange to relate, both were attempting to explore the inside of the detonator. They held the detonator in one hand, and took hold of the wires, and attempted to gently pull them out to see what was inside, or to ascertain whether the ends of the wires were properly fixed in the plug. One man was an expert

from the explosives company. The other man was a collier, who tried to do the same thing, and with the same result—the detonator exploded. It became a serious question whether, in pushing the detonator down, while charging the shot, there was not a liability to pull the wires out and fire the detonator, unless the charging was done by men trained to the work. With some of the high explosives, it was necessary that the detonator should be in actual contact with the explosive. In the present invention, it was encased in a strong paper tube. Would that have any effect on the explosive? And were they sure that the detonator would fire the explosive when surrounded by a strong paper cylinder? Then as to a miss-shot, how was it to be dealt with when the detonator was put in as shown? How was it to be recovered? He did not yet see any way of dealing with it in such a tube. They might put in another shot at a safe distance away, and a competent official would then have to recover the miss-shot. Supposing he found the cartridge with the detonator, what was he to do with it? For his own part, he only saw one method of dealing with a recovered cartridge that had mis-fired, that was, to at once place it in the cartridge-tin, take it to the surface, and, after opening the bottom of the cartridge, place it in a bucket of water until it was all dissolved. The water could be thrown away in a field, and the detonator, with wires, burnt in an open fire. He could not see how they could safely withdraw the detonator when inside the paper tube, without grave risks.

Mr. M. DEACON (Sheepbridge) agreed with Mr. Stokes that the detonator did not require hard ramming if it was properly rammed, and he believed that at most collieries it was well understood how detonators should be treated. On the other hand, if there was any risk of accident, and if there was some advantage to be gained from this invention, the members ought to consider it carefully; and he would be sorry to oppose any invention which would lessen the risk of accident. He would like to know how many shots had been fired by this apparatus, and how many miss-shots there had been. He was not by any means sure that they were on the right lines in abolishing powder and the old fuze, and taking to high explosives. While there might be less risk of fire-damp explosions, there certainly had been a great many accidents from detonators, which he considered the most dangerous things that any person ever had to handle. He would not go near them if he could possibly help it, especially since a special representative of an explosives company, sent to examine into the cause of miss-shots at one of his collieries, had his fingers blown off.

Mr. G. J. BINNS agreed with Mr. Deacon that detonators were fully as dangerous as represented.

Mr. STOKES observed that some of the explosives were very much like sawdust, and when mixed with coal might be sent away, and if ignited the material would simply burn without danger. The danger was due to the detonator, and he did not see how the charge or detonator was to be recovered without risk to the workmen unless great care was exercised. In some of the explosives, of course, the material could be gathered up intact.

Mr. DEACON remarked that in the case of a miss-shot occurring in ripping, there would be an additional danger supposing that the miss-shot remained embedded in the rock which had been blown down and had to be broken up before it could be removed. The workmen would practically be applying another form of detonator in the shape of a sledge-hammer, and though the shot had missed in the first instance, it was exceedingly likely to go off in the second.

Mr. STOKES said that a piece of rock like that might be quietly put in the waste and the shot left to posterity to fire.

Mr. DEACON observed that the rock might fall right across the gate-road.

Mr. BINNS remarked that it was not unusual in the case of ripping rock to have another shot put into a large stone lying on the ground.

Mr. J. MEIN, in reply, said Mr. Walker was quite aware that it was contrary to rules and regulations to indulge in excessive ramming, but it did not require excessive ramming to fire the detonator. The object of the invention was to avoid the possibility of any accident of that character, and they knew, however careful the workmen, that sometimes the least blow would fire one of these charges. It required very little force to push the detonator along the tube, and the cane springs only came in contact with the copper portion at the end of the cap. As to miss-shots, Mr. Walker informed him that he could pull the tube back, withdraw the detonator, and put in a new one, so that the danger from miss-shots was altogether avoided.

Mr. WALKER said that he had only fired three shots and had had no miss-shots with his apparatus. He had fired one shot in ripping, and one in coal at Blackwell colliery, in the presence of Mr. Todd, who was of opinion that it did its work well.

Mr. A. S. DOUGLAS (Hucknall Torkard) asked whether the shot did its work as well as if the detonator had been embedded in the explosive?

Mr. WALKER said that he had been a practical miner from his youth and had been accustomed to shot-firing with high explosives, and he could guarantee that with his invention and method a ripping shot would do its work with 2 ounces less of explosive.

Mr. H. R. HEWITT (Derby) wrote that it appeared to him that there was very little use for the Walker apparatus. All high explosives should be fired by an electric battery, in which case the hollow needle would have to be of large diameter to admit the fuze-wires, thus leaving a large portion of the shot-hole unstemmed. This stemming could not be made up in a satisfactory way, and the probability was that blown-out shots would be caused by the weakness of the stemming when the needle had been withdrawn. It was obviously absurd to use gunpowder-fuze to ignite high explosives; and if this apparatus were used, it appeared to be an impossibility to ensure that the detonator was in the explosive, and miss-shots would ensue. With this arrangement, the detonator could not be firmly embedded in the explosive charge, nor could the mouth of the shot-hole be closed. These were two necessities for successful shot-firing which, if neglected, would interfere with the success of the exploded charge. He could not agree with the author that accidents frequently occur whilst ramming a shot-hole, by neglecting to place the detonator sufficiently deep in the cartridge. If this did occur, it was entirely the effect of carelessness, and workmen must be shown the necessity of placing the whole of the detonator in the front cartridge.

The PRESIDENT proposed a vote of thanks to Messrs. Maurice and Mein for their papers, and to Mr. Walker for exhibiting his ingenious apparatus.

This motion was seconded and carried, and the discussion on the papers was adjourned.

DISCUSSION UPON MR. G. J. BINNS' "NOTES ON AUXILIARY HAULAGE AT NETHERSEAL COLLIERY."*

Mr. BINNS remarked that the criticisms upon his paper could be divided into two parts: firstly, the relative efficiency, or rather advisability, of air and electricity as methods of transmission of power; and, secondly, other matters. As to the relative efficiency, this was answered

* *Trans. Fed. Inst.*, vol. xiii., page 256.

by Mr. W. Spencer, who remarked that it did not matter much, under the circumstances, whether electricity, or steam, or compressed air was the motive power; the paper was not intended to, and did not, enter into this portion of the subject, on which a diversity of opinion might exist. In the case of so varied a utilization of power as that under discussion, comprising numerous intermittently driven engines—pumping, rock-drilling, and ventilating by compressed-air jets—it was difficult to see how any reliable result as to the efficiency could be arrived at. There was one aspect of the case which had not been dealt with, but which was not without importance, and that was, safety. In adopting the system in use that consideration had very great weight, and he might be allowed to make mention of a few misadventures, culled from recent literature, which had been caused through the use of electricity, although in doing so he did not wish to open up a controversy. The bulk of these instances occurred only during the last three months. In the London *Daily Telegraph* of March 19th, 1897, appeared an account of the funeral of a workman who had been killed by an electric shock at the Hampstead electric lighting works. Mr. Reed, the chairman of the lighting committee, said that the accident was totally without precedent in the annals of electric lighting. In the ensuing month appeared an account of an accident, in Paris, to a tram, which was discovered to be on fire, the accident being attributed to a rupture of one of the electric wires. On the 27th of the same month, another tram, in Paris, had barely started when the conducting wire snapped and transmitted a shock along the line, killing two horses. The superintendent of the Chicago fire-brigade reported that, of 106 cases of fire attributed to electricity, only 95 were actually due to that cause. Other instances were given in Paris, in London, and in Bournemouth. Mr. Binns remarked that it seemed to him that if these accidents had occurred in mines the results would have been much more serious and far-reaching in their consequences. On the same subject he could not do better than quote Mr. Sydney F. Walker's opinion on electric haulage:—*

> With underground electric haulage, however, considerable difficulty has arisen in consequence of the ever-varying nature of the load. . . . This variation of load brings a considerable strain on certain parts of the motor, and creates a considerable tendency to sparking at the brushes. Both of these difficulties have been provided for in the latest form of motors, by strengthening those parts on which the strain falls, and by more perfect design; but the further trouble, that with the driving engine of the generator, is not so easily provided for [reference to difficulty in designing a perfect governor]. Serious damage is often done to valves and their spindles, or even to piston-rods, by these sudden fluctuations.

* *Colliery Guardian*, 23rd July, 1897, page 152.

Upon the second part of the criticism as to the drawing of timber, it appeared from a perusal of Special Rule 71 that this course was illegal, and, as a ringer-and-chain was the only allowable method of drawing timber, any new inventions were not permissible until that rule should be amended. On enquiring further, he found that, on the few occasions when the engine-rope was used for drawing timber, the timber was not supporting any roof, but was half buried in the waste. At the same time, he could not see how, by keeping a long distance away from the prop to be drawn, the workman was incurring any unusual danger; indeed, he thought it could not be so much as if he were close to, as with the present mode. It had been a difficult thing to arrive at the cost of ropes, but an attempt had been made, which resulted in a cost of 0·217d. per ton, and it was certainly not more. His paper was only an extended discussion of Mr. Galloway's paper on "Secondary Haulage;" * it was not intended to be, nor was it an extended treatise on the relative advantages of electricity and compressed air.

Mr. H. R. HEWITT wrote that Mr. Binns had made use of the power which was already in his possession, and was, he thought, getting results which could not be excelled by any other power under the conditions worked at Netherseal colliery. That colliery must be visited before anyone could comprehend the very extended use to which Mr. Binns put the small haulage-engines worked by compressed air.

The further discussion was adjourned.

DISCUSSION ON MR. JOHN PIGGFORD'S PAPER ON "ELECTRIC HAULAGE AT PLEASLEY COLLIERY." †

Mr. H. R. HEWITT asked whether Mr. Piggford had had any difficulty owing to the armatures of the motors breaking up, through either overloading or underloading the machine? Some time ago, an electric coal-cutting machine was running free of load, when the armature broke up altogether; first the binding, and then the wrapping wires snapped in such a way that the armature was useless until it had been rewound. Knowing this, and that it will also occur when the motor is overloaded, and that haulage-ropes cannot always be carrying a constant load, it appeared to him to be a very open question as to whether electricity was the best power under all the conditions of coal-mining.

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* *Trans. Fed. Inst.*, vol. xii., page 257. † *Ibid.*, vol. xii., page 633.

DISCUSSION ON MR. E. B. WAIN'S PAPER ON AN "IMPROVED APPARATUS FOR DRAWING TIMBER IN MINES."*

Mr. G. J. BINNS said that the pulling-jack was a very ingenious invention, but Special Rule No. 71 of the Midland Inspection District prohibited the use of any means of drawing timber but by a ringer-and-chain. If the author of the paper had not taken such pains to explain that the invention was not a ringer-and-chain the members might have persuaded themselves that it was, but the author had expressly stated that it was not.

The PRESIDENT did not himself think that the use of the apparatus would be illegal, as the rule meant some such apparatus as the ringer-and-chain.

Mr. J. H. W. LAVERICK (Alfreton) was of opinion that the apparatus combined the ringer-and-chain. If the appliance could be used in drawing back timber it would be very useful.

Mr. A. S. DOUGLAS pointed out that Special Rule No. 71 provided that a ringer-and-chain only was to be used for drawing timber under heavy roofs. The apparatus would be useful if this objection could not be overcome, for withdrawing timber where the roof was not heavy, but where the props were very fast.

Mr. W. H. HEPPLEWHITE (H.M. Inspector of Mines) was of opinion that the apparatus was a ringer-and-chain. The apparatus just exhibited, he was afraid would not be suitable for withdrawing back props in the Midland Inspection District, where three rows of props were usually set; and to attach the apparatus on the second to withdraw the third row, a person would have to manipulate the lever by standing partly under the roof from which the support had been removed, whereas in the present form of ringer-and-chain a person stood between the face row of props and the second row.

The meeting then terminated.

MEMOIRS OF DECEASED MEMBERS.

Mr. WILLIAM ARMSTRONG died at his residence, Pelaw House, Chester-le-Street, on November 3rd, 1896, in his 85th year. He was the son of Mr. William Armstrong, a former treasurer of the borough of Newcastle-upon-Tyne.

* *Trans. Fed. Inst.*, vol. xii., page 591.

He was educated at Dr. Bruce's academy in Newcastle-upon-Tyne and afterwards at the University of Edinburgh. He served his time under the late Mr. Nicholas Wood at Killingworth colliery, in Northumberland, since closed. His first appointment was at Jarrow colliery, whence he removed to Wingate colliery, in the county of Durham, and afterwards, in 1870, to Pelaw House, near Chester-le-Street, where he spent the remainder of his days.

It was he who fought the wire-rope question, and for the skilful manner in which he dealt with that difficulty a special vote of thanks was sent to him by the Northumberland and Durham coal-owners in the year 1838.

Since 1870, he devoted himself almost entirely to consultation work, and for over 30 years he acted as consulting mining engineer to the North Eastern Railway Company.

He was a wellknown figure in Newcastle-upon-Tyne, and was generally regarded in the North of England as the father of the coal trade, his advice being sought in almost every difficulty that arose; in fact no man in his profession was more trusted or more respected.

He was engaged on all of the important arbitrations which took place between the Durham coal owners and their workmen, generally taking the leading part as advocate of the owners' case, and it was owing to his initiative and exertions that the Durham Coal-owners' Association was formed. His services were always freely given, and he declined to take any fees for the large amount of time which he willingly gave in all matters relating to the coal trade.

For several years he was consulting mining engineer to Messrs. Bolckow, Vaughan, & Company, the Staveley Coal and Iron Company, the Sheepbridge Coal and Iron Company, the New Tredegar Company, and was engaged in nearly all the more important valuations throughout the trade.

He was an original member of the North of England Institute of Mining and Mechanical Engineers, founded in 1852, and he joined this Institution immediately after its formation in 1871.

Mr. Armstrong retained his naturally robust health and keen mental faculties to the end, and although his friends and relatives had during the month previous to his death noticed a change, yet the end came very rapidly, he having transacted business during the early part of the day, and it was only in the afternoon that the heart's action gave way. He died in his library, without himself being conscious that his end was approaching.

Mr. RICHARD J. STRICK was born at Swansea on March 25th, 1850.

In 1866, he commenced his training as a mining engineer under his brother, Mr. John Strick, at Shelton collieries. In 1874, he undertook the appointment of manager of the Butterley Iron and Coal Company's collieries in Derbyshire and elsewhere, under the late Mr. Bean, who was the general manager of the collieries and works. He held that appointment until Mr. Bean's death, when he took the full management. Later, he removed from the Portland collieries, Derbyshire, to the Silverdale collieries and ironworks, Staffordshire, acquired by the same company, and had the management until 1888.

After that he had general work, in the course of which he re-opened the Mossfield colliery after the explosion. He also went out to Turkey to report on coal-mines near Heraclea. From 1892 to 1895, he was manager of the Cossall colliery. About 2 years before his death his health failed, and he was unable to take any appointment. He died at The Mumbles, near Swansea, on March 12th, 1897.

He became a member of the Chesterfield and Midland Counties Institution of Engineers on January 2nd, 1875, and so continued up to his death. For several years he was a member of the Council.

Mr. HENRY AMOS KNIGHTON was born at Eastwood, on October 5th, 1839. He at first worked as a miner at Plumptree colliery, under the Butterley Iron and Coal Company. In 1865, he became a deputy underviewer under Messrs. Barber, Walker, & Co., of Eastwood, and held that position until 1873. He then entered into a partnership, and opened a footrill colliery, called Springfield, at Hill Top, Nottinghamshire. After some years, this pit was drowned out and abandoned. In 1880, he sat at Derby for a certificate of competency, and gained a first class one. In the same year, he obtained a situation as colliery manager at Bagworth, Leicestershire, and held that appointment until his death, which was caused by injuries resulting from his attempt to alight from a locomotive whilst it was in rapid motion. He died at Bagworth on September 11th, 1895. He was for many years superintendent of the Wesleyan Sunday school at Eastwood. He became a member of this Institution in July, 1874.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN MASON COLLEGE, BIRMINGHAM, OCTOBER 11TH, 1897.

MR. R. S. WILLIAMSON, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The SECRETARY then read the Annual Report of the Council as follows :—

THIRTIETH ANNUAL REPORT OF THE COUNCIL.

The Council have pleasure in congratulating the members upon the completion of a successful year. The Institute has improved both in finances and members.

The members now upon the list number 161 as against 151 last year. Seventeen new members of different classes have been elected, 6 have resigned, and 1, Mr. W. Farnworth, who was for a long time connected with the Institute and was President in 1882, has unfortunately died.

The income of the year has been £239 15s. 6d., and the expenditure £168 16s. 5d., so that the bank balance has been increased by £70 19s. 1d., and now stands at £407 10s. 4d.

There have been 5 general meetings, 6 council meetings, and 1 meeting of the Technical Education Committee held. The latter committee continues to arrange the papers and examinations, and generally supervises the mining lecture-scheme for South Staffordshire in connexion with the County Council.

At the annual general meeting Mr. R. S. Williamson gave an instructive inaugural address, as President, upon the advancement made in mining science, principally since 1874.

The following interesting papers have also been read :—

"Bumps at Hamstead Colliery." By Mr. F. G. Meachem.

"The Duty of Cornish Pumping Engines, past and present, and as compared with others." By Mr. Nicholas Trestrail.

"Saving Life in Colliery Explosions." By Mr. E. J. Bailey.

Moreover, a very important lecture was delivered to a large audience by Dr. John S. Haldane, upon the effects on man of the gases commonly met with in mines.

The Institute is still upon the list of Corresponding Societies of the British Association for the Advancement of Science, and the reports of its proceedings, together with the transactions of many of the leading British and Foreign Societies, may be referred to at the institute room, 3, Newhall Street, Birmingham.

The Federated Institution of Mining Engineers with which you are connected has now a membership roll of 2,494, and has published for the year two volumes of *Transactions*, embodying 91 papers, upon geology, mining engineering and safety-appliances, mechanical engineering, colliery-explosions, coal-dust, safety-lamps, mine-ventilation, preparation of minerals, explosives, blasting, electricity, etc., together with "Notes of Papers" on the working of mines, metallurgy, etc., from the transactions of colonial and foreign societies, and colonial and foreign publications.

Meetings have been held in South Wales, Lancashire, and London, and a Students' Meeting in South Yorkshire. Committees have been formed to consider the questions of mechanical ventilators, explosives, and the incorporation of The Federated Institution of Mining Engineers, and the latter has recommended that application be made for a Royal Charter of Incorporation in the name of The Institution of Mining Engineers. It is also in contemplation to adopt a class of Fellows to be selected from members of the Institution.

In September, 1898, The Federated Institution of Mining Engineers will hold their Annual General Meeting in this district, and every effort should be made by this Institute to render the said meeting a great success.

Your thanks are again due, and are hereby tendered to the authorities of Mason College for providing rooms for the meetings.

An effort is being made to increase the list of members, especially of the associate class, by sending special circulars to mine managers calling attention to the great advantages to be gained, and urging them to influence their under-managers to become associates, and participate in the benefits which must be of the greatest importance to them.

The Council particularly request every member to further this effort as much as he possibly can.

Dr. THE TREASURER IN ACCOUNT WITH THE SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1897. **Cr.**

	£	s.	d.
To Bank Balance ...	336	11	3
„ Subscriptions Received	232	14	6
„ Sale of Transactions ...	1	10	0
„ Bank Interest ...	5	11	0
	£576	6	9

	£	s.	d.
By Calls paid to The Federated Institution of Mining Engineers ...	76	13	1
„ Secretary's and Reporter's Salaries ...	50	0	0
„ Rent, Rates, Gas, etc., of Institute Room ...	20	0	0
„ Subscription to Mason College ...	4	10	0
„ Expenses of attending Meetings of The Federated Institution of Mining Engineers and Audit ...	2	14	6
„ Stamps, Parcels, and Telegrams ...	5	4	4
„ J. Goodman & Sons: Printing Circulars, Membership Lists, etc. ...	6	2	6
„ R. Jones: Lithographing Circulars ...	1	3	0
„ Caretaker at Mason College ...	1	0	0
„ Purchase of copy of Prof. Jukes' paper on the South Staffordshire Coal-field ...	0	8	6
„ Andrew Reid & Co., Ltd.: Excerpts, Transactions ...	1	0	6
„ Balance in Bank ...	407	10	4
	£576	6	9

BALANCE SHEET, 1896-97.

Liabilities.	£	s.	d.
To The Federated Institution of Mining Engineers ...	47	12	0
„ Balance ...	443	12	10
	£491	4	10

Assets.	£	s.	d.
Balance in Bank ...	407	10	4
Subscriptions due ...	83	14	6
	£491	4	10

Examined and found correct,

DANIEL ROGERS.

October 11th, 1897.

This is exclusive of considerably more than £100 worth of property, for which no credit is taken.

The report was adopted on the motion of the CHAIRMAN, seconded by Mr. PEAKE.

ELECTION OF OFFICERS, 1897-98.

The SCRUTINEERS reported that the following officers had been elected for the ensuing year:—

PRESIDENT.—Mr. W. H. WHITEHOUSE.
VICE-PRESIDENT.—Mr. JAMES LINDOP.

COUNCIL.

Mr. G. C. ROBINSON.	Mr. D. ROGERS.
Mr. ISAAC MEACHEM, Jun.	Mr. W. B. COLLIS.

The SECRETARY stated that, owing to ill-health, Mr. Whitehouse was compelled to decline the presidency, and Mr. Williamson had been requested by the Council, and had consented, to remain in office for another year.

Mr. W. F. CLARK proposed a vote of thanks to the President and officers for their services during the past year. Whilst praise was due to all the officers, there could be no doubt that the President had discharged his duties in the most admirable manner. Mr. Williamson was connected with an important mining enterprise, whose extensions were rapidly going on. He had not been slow in adopting improvements, and when adopting them had taken a very intelligent view of their advantages and disadvantages. At the same time, Mr. Williamson had been most ready and willing to give the Institute the benefit of his experience.

Mr. JOHN WILLIAMSON seconded the motion, and it was supported by Mr. C. H. TREGLOWN, and carried.

The PRESIDENT, in responding, said that it would give him great pleasure to work in his present capacity for another year. Whilst there had been some success, as shown by the report, there was room for improvement. Their members were increasing in number, and they had advanced financially, but he thought it was time that more interest was evinced by the giving of instructive and appropriate papers. He regretted very much that Mr. Whitehouse, through ill-health, was unable to accept office. He moved that a letter of hearty sympathy be sent on their behalf.

The motion was seconded, and unanimously approved.

The following gentlemen were elected :—

MEMBER—

Mr. FRANK OWEN, Mining Engineer, Venezuela.

ASSOCIATES—

Mr. THOMAS LONGSTAFF, Under-Manager, Pool View, Hednesford.
Mr. THOMAS LINDSAY, Under-Manager, Cannock Wood Mine, Hednesford.

STUDENTS—

Mr. RICHARD HAWTHORNE GREAVES, Camborne.
Mr. SYDNEY EDGAR THOMAS, Cannock and Rugeley Collieries, Hednesford.

Mr. H. G. GRAVES read the following paper on "Irish Legislation on Mining and Coal up to the Year 1800" :—

IRISH LEGISLATION ON MINING AND COAL UP TO THE YEAR 1800.

By H. G. GRAVES, Assoc. R.S.M.

The mineral wealth of Ireland is greater than is generally supposed, and though our sister island has never taken a leading place, she has from time to time contributed a not inconsiderable proportion of the world's production. The copper-mines in county Wicklow were at one time famous, though now practically none of the ore is worked in the country. Between 1787 and 1811, the Cronebane mines, in the sweet vale of Avoca, produced some 26,800 tons of ore yielding 1,700 tons of copper, and, just before the middle of this century, Sir Robert Kane, in his work on the *Industrial Resources of Ireland*, speaks in high praise of the same deposits, and also of the Tigroney and Ballymurtagh districts in Wicklow, Knockmahon in Waterford, and the southern portions of Cork and Kerry as copper-producers. Lead-ore, especially argentiferous galena, is even more widely diffused, and is still worked, although in small quantities. Tinstone has been found in small quantities, and small amounts of gold have occasionally been worked in Wicklow, where the largest nugget weighed 22 ounces. Many gold ornaments of native workmanship show that, at an early period, a considerable amount of the precious metal must have been produced. Amongst the other minerals are iron-ore, iron-pyrites, salt, barytes, and ochre, and the famous Irish bauxites must not be forgotten. It is of course, an Irish grievance that nature has removed most of the coal-deposits, but some consolation may be derived from Prof. Hull's statement that in county Tyrone there is a tract extending to the borders of Lough Neagh overspread by Triassic and Tertiary strata, under which coal may be supposed to lie.

Perhaps the present state of the Irish mineral industry is best shown by the mineral statistics for 1896. The amount of coal worked was 129,585 tons, valued at £53,635 or 7s. 11·32d. per ton; and 5,380 tons of fire-clay valued at £941 were worked under the Coal-mines Regulation Acts. The total number of mines was 23, distributed as

follows :—Leitrim 2, Roscommon 4, Kilkenny 4, Queen's 2, Tipperary 6, Antrim 1, and Tyrone 4. Altogether 971 workpeople were employed, and there were 3 non-fatal accidents.

Under the metal-mining acts there were 29 mines, of which Antrim had 18, Down 1, Donegal 1, Wicklow 4, Sligo 1, and Cork 4. The workpeople numbered 648, and there was 1 fatal accident. The minerals produced amounted to 155,997 tons, valued at £30,571, and they included bauxite 7,249 tons, iron-ore 95,819 tons, rock-salt 42,919 tons, ochre 809 tons, cupriferous pyrites 328 tons, iron-pyrites 2,400 tons, lead-ore 82 tons, and barytes 6,391 tons. There were also about 3,600 persons employed in 549 quarries which produced 848,203 tons.

Although the mineral production is now too insignificant to have anything beyond a local concern, it may be of interest as a contribution to mining history to point out that, prior to 1800, mining received a considerable amount of attention. Indeed, the legislative enactments of the Irish Parliament during the eighteenth century include many that deal directly or indirectly with coal-mining and the coal trade. Before the year 1705, it is doubtful whether coal or mines are even mentioned; but this is scarcely to be wondered at, for colliers and collieries until the beginning of this century attracted only the scantiest attention. In the United Kingdom, the Scottish Parliament claims priority in the consideration paid to coal-mining, and their first act, dated 1661, when, judged by present-day standards is as black as the coal itself, as it practically made into slaves all the "coilzearis, salteris, and coilberaris." England waited until 1736, when she adjudged persons who set fire to coal-mines as guilty of felony, and worthy of suffering death without benefit of clergy. Ireland preceded the latter country by several years, and made the same law, with several other heavily-penalized additions regarding embezzling and damage as early as 1727. Coal itself, however, is first mentioned in an act dated 1705, and entitled "An Act to regulate the taking and exacting of tolls throughout this Kingdom, and to prevent the engrossing of coals in the City of Dublin." This particular act was the first of a series which was intended to keep down the price of coals in the capital, an object that occupied a very large share in the legislation devoted to mining and its products.

The inspection of mines was an undreamt-of factor, and the mechanical engineering side of mining was scarcely considered by law, unless the felonious action of firing a mine or damaging an engine or any

works could be considered as being included within the province of the mining engineer. Labour problems or the relation of master and servant on the one hand, and the rights of exploring for working the minerals, together with the powers of leasing and holding mineral lands on the other hand, gained a very fair amount of attention.

The statutes of the Irish Parliament have twice been published in full, once in fourteen octavo volumes, dated 1794 to 1818, and once in twenty folio volumes, dated 1765 to 1801. They include all the acts, so far as they are known from 1310 to 1800, and are indexed very fully. Both sets have been consulted in compiling this paper.

The legislation under consideration, comprising over forty separate acts, naturally falls into several groups, although many of the acts cover more than one of these divisions, which are as follows :—(*a*) Mining and its encouragement ; (*b*) the price and supply of coal ; (*c*) the coal-yards ; (*d*) damage and theft ; (*e*) labour ; and (*f*) coal-dues and import duties.

(*a*) Mining and its Encouragement.

In 1404, an act was passed in the English Parliament, and is given in full below :—(5 Henry IV. c. 4), "It shall be felony to use the craft of multiplication of gold or silver." "Item ordeignez est et establiz qe nully desorenavant use de multiplier or ou argent ne use le art multiplication et si null le face et de eo soit atteint qil encourage la peyne de felonie en ce cas."

This craft of multiplication of gold or silver has rather an alchemical appearance, but it was certainly regarded as applying to mining and was specifically repealed in England in 1689 by 1 William and Mary, c. 30. It was in force in Ireland, owing to an Irish act of King Henry VII., passed in 1495, and entitled "An Act confirming all the Statutes made in England." The Irish Parliament therefore dissolved it in their first mining act which was passed during the fourth year of Queen Anne's reign, 1705, and was called "An Act to repeal the Statute made in the fifth year of King Henry IV. against Multiplying Gold and Silver, and to prevent disputes and controversies concerning Royal Mines." After reciting the effect of the prior act, it is said that great skill had been attained during recent years in the arts of extracting metals, but owing to the fear of possible penalties this knowledge was exercised abroad instead of in the country. Further sections exclude mines of copper, tin, iron and lead, from the description of royal mines which are for gold and silver, but power is reserved to the sovereign to buy any clean and

merchantable ore within 30 days after it is raised, at the rate of £16 per ton for copper-ore, £2 for tin and iron-ore, and £9 for lead-ore. To encourage the search for and working of minerals, the monopoly granted to the Earl of Abercorn, under letters patent from King James II., was abolished, and he received a compensation of £4,000. This monopoly bore a rental of £10, and was very exhaustive, covering the working of minerals and the sale of coal nearly all over Ireland.

Eighteen years later, in the reign of King George I., further encouragement was given to finding and working mines. As many owners, such as bishops, colleges, and life-tenants, were unable to work mineral-lands, they were empowered to grant leases for 31 years, taking as rent one-tenth of the value of the ore extracted. The conditions of leasing were fully set forth, and houses, churches, etc. were protected. A lease was void if work was not begun within a year, or afterwards if 6 men were not employed for 150 days in the year.

Some doubt had apparently been expressed as to whether this leading act covered coal-mines, and it was definitely settled that it did so do by an act of 1741, in the next king's reign. Eight years later, another act with the same title, viz., "An Act for explaining and amending an Act intituled 'An Act for the further encouragment of finding and working minerals within this Kingdom'" gave persons empowered by the first act the right to lease coal-mines for 41 years at rents not under twopence per ton. The Archbishop of Armagh was also enabled to work coal on school-lands granted by King Charles I. and the rights of life-tenants were more fully dealt with. Further encouragment was given in 1751, by a section of a miscellaneous act which enabled roads, drains, and canals to be built, repaired, and used by coal and other miners. These powers were increased in 1792, and mining companies were enabled to build roads at their own expense from the mines to the next road or sea, provided that they were not above two miles distant and that they satisfied the landowners on valuation as in the case of the royal canal. In 1796, roads leading from any market town to any colliery were aided. In this connexion, it may be noticed that road-making was much more advanced in Ireland than in England, during the second half of the eighteenth century.

Irish collieries were offered a bonus, in 1757, of 2s. per ton on coal brought by sea to Dublin, and this was extended to coal brought by canal in 1771. In 1800, it was ordered that the first-named act be continued in force for 7 years. Import duties on English and foreign coal were not applicable to Irish coal, according to the acts of 1781-4.

The linen manufacture in the counties bordering on Lough Neagh evidently depended upon the coal, and Drumglass colliery, in Tyrone, was to be favoured by a track or waggon-way to the lake so as to supply the coal more readily. An act, in 1789, granted £2,000 to Messrs. John Staples and James Caulfield on condition that they made the road in two years under a bond of £4,000. In 1791, the Grand Canal Company received facilities for carrying a canal to Kilkenny collieries.

Despite the endeavours to increase the local trade, no great measure of success appears to have been attained. According to Mr. Arthur Young's *Tour in Ireland* (1776-1779), the average annual imports of coal were 180,113 tons between 1764 and 1770, rising to an average of 204,566 tons in the next 7 years. The bounties paid between 1761 and 1777 inclusive, on Irish coal brought to Dublin, amounted to a trifle over £2,470. The yearly payments varied betweeen a minimum of £75 4s. in 1767 to a maximum of £220 3s. 10d. in 1762, and the average over this period of 17 years was £145, representing, at a bounty of 2s. per ton, only an annual average of 1,450 tons. The same author comments very strongly on the failure in carrying the canal between the sea and Newry as far as the Drumglass and Dungannon collieries, and on the small out-turns of the latter though they were capable of greater things.

As throwing some light on the subject, it may be of interest to quote part of a letter dated March 22nd, 1771, from Sir Lucius O'Brien, to James I. Earl of Charlemont. After referring to the appointment of the Earl to be governor of the Tyrone Colliery Company which had been incorporated by charter in 1765, the letter continues . . . . "as our coal bill through ministerial influence has been defeated, what I would propose in the place of it is that your lordship should propose at the Dublin Society that that body should give a premium of 1s. a ton for the first 10,000 tons of Irish coal brought to Dublin by water for each of the 3 succeeding years . . . . English coals pay a duty of 7d. per ton which is saved on our own, the parliamentary premium now subsisting is 2s. a ton, and the additional 1s. would thus give our merchants 3s. 7d. advantage over the Whitehaven merchant. I am sure after some time, 2s. 7d. would be sufficient advantage . . . . we might easily procure all the public buildings whose firing is provided at the public charge to burn these coals." The Dublin Society at that period, it may mentioned, had been very active in promoting various local industries by bounty and otherwise.

Besides these acts of public importance, there were three or four com-

pany acts which were to be considered as public acts. The first of these, in 1791, incorporated the Royal Mining Company as soon as 10 per cent. of a public subscription of £25,000 capital was paid in to the hands of the treasurer, Sir W. G. Newcommen, Bart. All kinds of mines, marble quarries, beds of clay, flint, ochre, and fuller's earth could be opened and worked. Next year, the Hibernian Mine Company was invested with similar powers. The Associated Irish Mine Company was incorporated in 1798, by "An Act for the better enabling persons to open and work mines and to raise coal, culm, minerals and fossils in this kingdom, and for working and manufacturing the same." The stock was not to exceed £100,000 and it is mentioned that the founders associated in 1787 had worked mines in Cronebane and elsewhere in Wicklow, and had expended £48,914 16s. 2d., independent of interest.

A royal mine was specially dealt with in an act of the thirty-seventh year of King George III., 1797. It was in the lands of Ballinvally, Moneyvickle, part of Kilpipe, called Coolbawn, and other lands in the county of Wicklow. An experimental grant of £1,000 had shown a likelihood of profit, so another £1,000 were granted. All the employees had to take oath to give up all gold, and the money in hand, as soon as it exceeded £1,000, had to be paid into the exchequer.

(*b*) THE PRICE AND SUPPLY OF COAL.

During the whole of this century, the price and supply of coal was a source of constant anxiety, which is evinced by an uninterrupted succession of acts. The earliest is the eighth act passed in the fourth year of Queen Anne's reign, 1705, and preceded the mining act which is numbered 12 of the same year. It was succeeded* in 1712, 1719, 1727, 1757 (two acts), 1761, 1763 (two acts), 1771, 1791, 1793 and 1800 by enactments generally increasing in stringency, and only once, by an act in 1781-2, was this method interrupted. Most of these acts apply to Dublin, but some of them were for Cork. Some attempts, it may also be mentioned, were also made to control the price of salt (*vide* 37 George III. c. 18). The various acts in the first part of the century are entitled as relating to the engrossing or ingrossing, forestalling, and regrating of [illegible] mark.

It would be both tedious and useless to attempt to follow all these acts in detail, and only their general tenour will accordingly be given. Heavy penalties, ranging as high as £100, half of which generally went to the person suing and half to the workhouse, could be exacted from

* Excluding expiring laws continuance acts.

persons entering into combination or otherwise enhancing the price of coals. In 1791, a third offence was punishable by the pillory, in addition to a fine and imprisonment at the discretion of the authorities. Therefore the coal must not be held back in the gabbarts or lighters more than 8 or 10 days, or bought up before the vessel comes to the quay.

At first the value of a reserve-supply was not recognized, so factors were prohibited from storing more than 1,000 tons in 1712, but this was increased to 1,500 tons 7 years later. Even then an excess was punishable by forfeiture of double the value of the coal. Wiser councils prevailed in 1793, when the provision of stores was encouraged by an annual grant of £800, which was to be distributed to pay the rent of grounds on which the coal was stocked by any factor or merchant within the limits of the Circular Road and Grand Canal, as long as 8,000 tons were sold and delivered within the year from the premises in respect of which the demand was made. Further, a bounty of 1s. per ton was paid for amounts over 4,000 tons stored for retail before January 1, 1794. At the same time, bounties amounting to £2,000 in the aggregate were to be given to barge and shipbuilders who built vessels to ply for 6 years, within certain limits on the Liffey and on the canals, at the rate of £1 per ton measurement. Thirty years before, the factors had not been allowed to keep boats, and they could only trade under licenses, of which but a limited number were issued, 40 for Dublin and 15 for Cork.

A very general provision in these acts was that a board attached to the mast of a lighter at a quay should bear the name of the place of origin of the coal and its price. Douceurs, called "old man," to anyone who had to do with coal were strictly prohibited, and in some cases the wages and rates of freight were specified. Infractions of rules were punishable by fines ranging from 40s. to £50, besides other pains and penalties.

The measures for coal were prescribed as early as 1719 and were repeated at intervals as follows :—

	Diameter in Inches.		Contents in Winchester
	Bottom.	Top.	Gallons.
Half-barrel	24	25½	20
Bushel	20	21	10
Half-bushel	15	16	5
Peck	11	12	2½
Half-peck	10½	11½	1¼

To ensure that good measure was given, the measuring porter was instructed, in 1793, to strike it once or oftener against the combings or side of the hatchway, while it was being lifted out of the hold. Another

precaution, of an earlier date, was to insist on a winch or windlass on deck, presumably for the purpose of bringing the measure up to the light before emptying it.

There was only one break in the series of oppressive acts and that was in the parliamentary session of 1781-2, when money was wanted for "making wide and convenient passages" through the city of Dublin. A coal due of 1s. per ton was then imposed for the purpose of raising the funds. To encourage the import, the act of 1719 and subsequent acts which restrained the coal trade were repealed, and anyone was allowed to buy and sell coal, how, when, and where he pleased. Evidently this was not successful, for, as we have seen above, another stringent law restricting the sale was passed in 1791. This state of affairs endured until 1832, when the British parliament specifically repealed all the acts above referred to and allowed free trade in coal both in Dublin and Cork. The duty of 1s. per ton on coal and culm for Cork was, however, continued, and vessels carrying coal to Ireland were still obliged to display a board showing its origin, description, and price. The employment of licensed meters was made optional, and six months later both inspectors and meters who were entitled to payments and fees before the prior act were compensated by pensions amounting to considerably more than £1,000 annually.

The endeavour to increase the supply by a bounty on coal of home production has been mentioned above, and a still more important attempt to reduce the price was made by instituting coal-yards.

(*c*) The Coal-yards.

In spite of all these regulations, with their corresponding penalties for infraction, it was found that prices always tended to ascend, and a radical departure was made in 1761, especially to meet the wants of the poorer classes and thereby incidentally to bring down the prices.

The tenth chapter of the statutes, in the first year of the reign of King George III., ordered that a yard for storing coal should be laid out in Dublin at the public expense, and that coal should be bought at prices at or under 16s. per ton and sold at or over 18s. Half-a-barrel, however, might be sold at a profit of 1s. per ton to any poor person who brought a certificate from a minister or other responsible person. The profits were to be devoted to the cost of maintenance, and, for starting operations, a sum up to £10,000 could be drawn from His Majesty's deputy receiver-general. A director was appointed at a yearly salary of £200, with two clerks at

£30, and the city authorities might make further rules. This act was to run for 2 years. At the end of that time, it appeared to be so useful that it was re-enacted, with some amendments, which stated who could give certificates, and allowed no more than 1 barrel daily to any one person. To avoid damage by long storage the old stock might be sold. Nearly 20 years later, in 1783, the buying price was raised to 17s. per ton and coal might be sold without the profit of 1s. The act of 1791 vouched for the utility of these yards, and gave power for new ones to be opened, and 2 years later the same power was again granted by the act, which offered a bounty to factors storing coal. In 1794, the directors of public yards were permitted to buy turf for the benefit of the poor in Dublin, and in 1800 the privilege was extended to Cork, where the coal-yards had also been instituted by a section of an act passed in 1765, but where the buying price had not been raised above a limit of 16s. before 1793. A caution to the directors to buy at the lowest price possible was at the same time interpolated.

(*d*) Damage and Theft.

"An Act for preventing the embezzling of goods under the value of 40s. by servants, and the malicious destruction of engines and other things belonging to mines," is the title of a very stringent act passed in 1727. Embezzling coal or ore, amongst other things, to a value between 5s. and 40s. rendered a person liable to be sent to a house of correction and to be publicly whipped on market day. Ore or coal in possession of a collier or miner to the value of 5s. had to be accounted for, or punishment followed. Anyone destroying engines or shafts for mines, or doing damage to the extent of £5, or setting fire to charcoal or coal on the surface, or to coal in a mine or working, was a felon, and might suffer death without benefit of clergy. Nine years later, a similar punishment was prescribed by the English Parliament for setting fire to coal-mines. Ireland, in 1783-4, extended the list of offences by a specific mention of damage to fire or other engines for draining collieries.

Many combinations for defrauding coal-owners led, in 1755, to a provision that colliers and others embezzling coal, and selling it without knowledge of the owner, were to forfeit to him 6d. per hundred, besides the cart and horse used. To render this more effective, the owner was ordered, in 1761, to give gratis to colliers, miners, buyers, and carmen a ticket inscribed with the quantity, date, and names. This had to be shown on request within 5 miles of the colliery.

(*e*) Labour.

Colliers and others skilled in working coal appear to have been scarce about the year 1751, when an act was passed to control their movements, and also to provide generally for wage disputes. No overseer, agent, engineer, pitman, sinker, collier, hurrier, banksman, car, cart, or waggon driver, labourer, carpenter, wrightsmith, or any person was to be enticed away or hired by another coal-owner or his agent under a fine of £5 for every 6 days during which the man had worked for the second employer. If, however, the man had not been paid his wages within 14 days after they were due, he might leave one master for another. The fine was recoverable as a civil debt, and 10 years later it was increased to £10, which was to go to the informer, in addition to other penalties. In the same year, the collier was ordered not to be absent from work, or to engage himself elsewhere, unless he wanted to go to gaol for 2 months, and to suffer other penalties. Refusal to work amongst the Dublin coal-porters was also made punishable from time to time. Previous to 1755, combinations of colliers and miners for the purpose of refusing to work, forfeited their wages due, and rendered the men liable to a month's imprisonment. This ordinance, which also refers to "the sending of threatening letters or with fictitious names subscribed thereto" was made perpetual in the first year of King George III.

Protection, however, was given to the workmen by a section of an act in 1765, which ordered the owner, under a penalty of £100, to pay the miners in ready money, and not in coal.

(*f*) Coal-dues and Import Duties.

Cork seems to have had the first allotment of coal-dues for improvement purposes. In 1735 there was "An Act for rebuilding the cathedral church of St. Finbarry in the city of Cork, and for erecting a workhouse in the city of Cork, for employing and maintaining the poor, punishing of vagabonds, providing for and educating foundling children." The money was to be raised by an import duty of 1s. per ton on all coal and culm for 31 years, and during the third year of King George III. this was extended 31 years from May 1, 1767.

Dublin received her share in the session of 1781-2 by "An Act for the improvement of the city of Dublin, by making wide and convenient passages through the same, and for regulating the coal-trade thereof." A duty of 1s. per ton was imposed on all coal other than that produced in the country, and to encourage the import, all restrictions on the coal trade were removed. These restrictions were, however, reimposed 10

years later, as has been described above. Coal for salt, sugar, and glass manufactories was exempt. From March, 1788, to 1810, an additional duty of 1s. per ton on all coal of extraneous origin was imposed in the session 1783-4 by an act which provided for raising money by loans on these dues. For improving Dublin harbour, and repairing the walls and quays on the Liffey, the colliers and coasters in the harbour had to pay 5d. per ton, according to an act of 1786, which was chiefly devoted to harbour regulations.

Import duties of 8½d. per ton were imposed on all coal, whether British or foreign, which came from Great Britain, and 10d. per ton on coal from other countries, according to a schedule of a financial act of 1794 (34 George III., c. 5), but section 126 of chapter 10 of the same year, states that coal-ships are not liable to any duty imposed that session when they paid a local duty exceeding 5d. per ton. Before that year, the duties were 7d. per ton.

Conclusion.

The author has endeavoured to trace, succinctly and yet completely, the history of coal-mining and coal in Ireland during the last century. It is a small subject, perhaps, but in its development it resembles that of many other trades. Take the woollen industry in England, for instance. No sheep allowed within 5 miles of the coast of Kent, except under severe restrictions, and shrouds had to be made of wool instead of linen. It was the spirit of the times, hampering legislation, intended by a paternal government for encouraging trade. Nothing much beyond parliamentary history has been introduced, but the law, as a rule, follows the popular requirements along its broader lines, and although on occasion it may be biassed by personal influence, still it may be concluded that a fair history of the subject, as a whole, is presented by such a research as is included in this paper.

A vote of thanks was passed to Mr. Graves for his paper.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
AUGUST 18TH, 1897.

MR. H. W. MIDDLETON IN THE CHAIR.

Mr. ANDREW BURT read the following paper on "The Methods of Working Minerals, Secondary Haulage, and Ventilation in Fifeshire":—

THE METHODS OF WORKING MINERALS, SECONDARY HAULAGE, AND VENTILATION IN FIFESHIRE.

BY ANDREW BURT.

We find, on looking over the annals of coal-mining, that the Fifeshire coal-field plays a very prominent part in that industry, it being among the first of the coal-fields of the kingdom to be worked. Coal was worked in this district as far back as the beginning of the thirteenth century, and probably before that date.

The monks of Dunfermline held various leases for the working of coal and other minerals in the neighbourhood of that town. One of these leases is dated 1291, when a grant was made by William de Oberwill of Pittencrieff to the abbot and convent of Dunfermline to work coal, etc., on that estate. Some of the old workings (or what were supposed to be old coal-mines) were found recently in the vicinity of the town during excavations which were being made for building purposes.

At this early period, the colliers were in a state of slavery (servitude) which continued more or less up to the seventeenth century. In 1600 (or about that time), an Act of the Scottish Parliament was passed which empowered the owners of the collieries, etc., to apprehend all vagabonds and sturdy beggars and set them to work. The colliers were then reckoned as part of the plant or estate, and were bought or sold along with the same when it happened to change hands. Tradition has it, that the estate of Halbeath, along with the colliery (the working of which

colliery forms the substance of this paper), the colliers and their families, were sold at one time for £300. This state of servitude lasted till about 1791, when the colliers received their liberty. The anniversary of this event was commemorated from year to year, and was a day of general rejoicing. The whole population of the village turned out and formed into procession, headed by a band, and paraded round the district. Some of the men were mounted on horses borrowed from the adjacent farms. This custom, however, has died out.

Coal is worked in Fifeshire both above and below the Millstone Grit, or from the true Coal-measures and the Carboniferous measures (Appendix A). The coal-bearing strata of these two measures are nearly 7,000 feet in thickness. In the eastern district of Fifeshire, the upper portion or true Coal-measures is being worked, while in the western district these upper seams have been denuded, and the lower portions or Carboniferous measures are left. The lowest workable seam, the Dunfermline Splint coal-seam, is worked extensively in the western district of the field. There is a thin seam of coal below the Dunfermline Splint, but it is of no commercial value and is not worked.

During the earlier operations, the coal was only worked opencast at the outcrop or for a very limited distance under cover, as no machinery of any kind was available at that time. In course of time, however, the workings began to extend under the surface, and to support the surface which was causing a good deal of trouble by its subsidence, small pillars of coal were left. These pillars, however, were very small and were soon crushed, and the works frequently lost for the time being. Small pits were then sunk and ladders fixed in them. The coal was carried up these ladders by women and girls with baskets or creels, somewhat similar to those used by fishwives. One of these baskets and a pair of boots were found in an old mine a few miles south of Edinburgh quite recently. The water was drained from these pits by small adit-levels. This system was called the pit-and-adit method of working coal, and some of these adit-levels are still in daily use in this district.

With the extension of the workings, the quantity of water in the workings also increased, and a machine termed the Egyptian wheel or chain of buckets was put forward as a contrivance to cope with this obstruction. One of the first coal-owners to use this machine in Scotland was Sir George Bruce at his Culross colliery in this district, and by the aid of this machine he was enabled to extend the workings of his mines for a distance of about 1 mile under the Firth of Forth. King James

VI., while hunting in this district, paid a visit to this colliery in the year 1617. He went down one shaft which was on the shore, and after going through the workings he came up a shaft which was sunk on an island about ½ mile out in the Firth.

Women and girls were employed below ground in the collieries near to the town of Dunfermline up till about the year 1849; and they are still employed on the pit-banks.

The seams of coal at present worked vary in thickness from 18 inches to about 20 feet. The system of working adopted is longwall with its various modifications, this being the system in vogue at all the collieries in the Fifeshire coal-field. One of H.M. inspectors of mines, Mr. Ralph Moore (now deceased), while speaking at a meeting of the members of the Mining Institute of Scotland, said that, "he thought they worked longwall in Fife better than at any place he had seen it in the eastern district, and if anyone had not seen a Fife longwall working, he would advise them to see it." The stoop-and-room system is also adopted, but in very few cases, only a small section here and there being so wrought where special precautions as regards surface-damages to buildings or other such like causes prevent the use of the longwall method.

Stoop-and-room Working.—In working by the stoop-and-room system, after the shaft or bottom pillars have been formed and main headings and levels set off, stoops of from 90 to 150 feet square or of a rectangular shape are formed. The roads which are driven at right angles to the cleavage of the seam are easier to work, and larger coal is got out of them than is the case with the roads which run parallel to the cleavage. These roads are driven from 12 to 14 feet wide, whereas the roads which run parallel to the cleavage are only made 7 to 9 feet wide. There is a lot of cutting in the roads which run parallel to the cleavage of the coal, as they are harder and more difficult to work, more dross is got out of them, and less round coal. They are accordingly very often driven farther apart than the other roads, and so make the stoop or pillar of rectangular form. It is customary to have each end or end-road blinded by the next stoop; that is, instead of the ends running in a continuous straight line as is the case with the level roads, each end is opposite to the next and following stoop similar to the jointing in a brick wall. This method does not allow of a large area of the roof being left unsupported, and so assists in the support of the roof. This working is termed working the whole or first working, and may be driven right out to the boundary of the field before the second working, or working of the broken, is begun. This

method is sometimes practised, but it is more common to follow up the first with the second working before the roof gets time to settle down. Where the first is immediately followed by the second working more round coal is produced than in the other method, as the stoops are not so much crushed and broken as when the roof and strata above have settled down.

In taking out the stoops, a road is driven right through the stoop both ways, cutting the stoop into four small stoops; then each of these small stoops is taken out in turn. They may be taken out by cutting a slice off the side of the stoop, and also off the side adjacent to this one, and this is followed up by other slices; but this method is not commonly adopted unless the stoops are small.

Longwall Working.—The longwall system, in which all the coal is taken out in one operation, is the one most commonly adopted, being practically used for all of the seams of coal which are worked in the district. From the main levels, headings are driven at distances of 210 to 240 feet apart, and from these headings the ordinary or branch roads are branched off level course. After the first heading has advanced a certain distance, the second heading which is 210 or 240 feet farther inbye the level is set up. This heading, as it advances, cuts off the branch roads from the first heading as they are driven forward. The branch roads from this second heading are in turn cut off by the next heading as it advances, and so on. The distance between these branch roads is about 45 feet, and the width of the roads about 7 feet. The face or wall of coal for each road is therefore about 45 feet, the same length as the distance between the branch roads. The face may be all to the rise side of the road, or may be partly on each side according to the inclination of the seam. In this district, it varies from horizontal to about 45 degrees.

Coal-cutting machinery has been tried on one or two occasions, but did not work very satisfactorily, and has now been entirely dispensed with. A Stanley heading-machine is working at one of the collieries.

The holing is made in the bottom, or in the middle of the seam if there happens to be a rib of daugh or fire-clay running through the coal. The small coal, when not fit to be sent to the surface owing to the mixture of clay, etc., which may be in it, is used to pack the walls and buildings. Stones for the walls or buildings are got by the brushing of the roof or overlying strata, or sometimes the floor, to get sufficient height for the drawing-roads.

There are one or two modifications of this system of working. In the Chemiss coal-seam, about 9 feet thick or more, and the Dysart Main coal-seam, about 20 feet thick in the eastern part of the county, and the Jersey coal-seam, from 10 to 15 feet thick, and the Lochgelly Splint and Parrot coal-seam, varying up to about 18 feet thick in the western part of the county. In these seams, the coal is worked in two operations, the lower portion of the seam being worked first and the upper portion afterwards.

There are one or two slight differences in the working of these seams peculiar to the colliery in which they are worked, but the general mode of working is much about the same. At Kingseat colliery, where the Jersey coal-seam (Appendix B) is being worked, and also the Lochgelly Splint and Parrot seam (Appendix C), the mode of working the first-named seam, which was adopted a few years ago, was as follows :—A section was commenced by driving a heading in the bottom coal or first working to the rise, and from this heading the ordinary roads were branched off level-course. These roads are from 36 to 45 feet apart and about 7 feet wide. To get sufficient height for the working-roads, the stone between the two parts of the seam is taken down, and sometimes part of the top coal also. The stone thus got is used for building purposes. This stone is of a varying thickness, and sometimes the whole of the top coal requires to be taken down so as to get sufficient height for the drawing roads. Roadside buildings are put in, these are 2½ feet or so across the face and consist partly of the stone got from the roof and partly of prepared pieces of wood 2½ feet long. The buildings are well packed with the dross coal which is made in the workings, or any daugh or fire-clay which may be thus got. No open cundies are left in the waste. A rib of fire-clay runs through the lower part of the seam and the holing is made in it. The thickness or length of the holing is regulated by the amount of stuff required to fill the waste and pack the buildings. When the weight on the coal-face is not very keen, the holing is made heavier. Rances or gibs are used very freely to keep up the face during holing operations. These are props or pieces of props varying in length up to 5 feet long. Figs. 1, 2, 3, and 4 (Plate VI.) are a general plan, a sketch of a working-place in the first working, section of coal-face, and the method of rancing respectively.

The second heading, which is driven as in the ordinary method of longwall and cutting off the branch roads as they are driven forward, is where the second working begins. After the second heading has cut off all the roads in the first heading, the working of the top coal

is commenced (Fig. 1, Plate VI.). This begins at the top end or innermost part of the heading, and is worked outwards. The first place is driven a few feet before the next place is started, and so on, each place being about, say, 10 feet in advance of its neighbour. The coal worked in this operation is taken to the lyes (stations) by the roads which were made in the first working, and as the faces move backwards the rails are lifted to be used over again in the next workings. Before this working has got back to the first heading, the roads begin to get very low and also narrow, and in order to get stones and material to pack and build the places, the roof is sometimes brushed a second time. If the material for this purpose happens to be a little scarce, open spaces are left in the old roads, but never in the waste. The holing of this second working is made in the waste of the first working. Figs. 5, 6, and 7 (Plate VI.) show the plan and sections of the working-face in this second working.

Some of the advantages of this longwall system are:—The whole available coal is wrought, the ventilation of the working-places is much easier than in the stoop-and-room system, and it is as safe, as economical, and as efficient as any of the other methods of working thick seams of mineral.

In one or two cases, the second working, instead of coming back, is worked forward about 60 feet or so behind the first working. The holing being done as in the previous case, viz., for the first working in the seam, and for the second working in the waste of the first working. Care, however, must be taken in this case to have the second working at a regular distance behind the first working. If it is too far behind the first working, the top portion is very much crushed, and the waste is too firm to hole in; and if it is too close to the first working the strata are not quite settled down, and, consequently, very unsafe to work. The coal is more difficult to work, and after it has been worked it is not so good as when kept at a regular distance behind the first working.

Gob-fires by spontaneous combustion are of frequent occurrence in the eastern district of the coal-field, but no such occurrence has happened in this district to the knowledge of the writer. A good means of preventing fire is to keep the area of the sections or districts as small as possible so as to get all the coal out quickly, and when the section is finished seal up the old roads and keep the air from getting into the gob. Fire readily takes place where the waste is not well stowed, and also near the rib-side.

In the working of the Splint and Parrot seam at the Kingseat

colliery, the lower portion is worked first; material is taken from the roof to give height to the drawing-roads, and to pack and build the roadside buildings. The remaining strata are allowed to fall, and the upper portion is worked on the top of these old roads, but sometimes new roads require to be made. The distance between these two workings may be as much as 300 feet.

Haulage.—The haulage may be in stages, the first being from the faces to the collecting-stations or sidings, and the second from thence to the pit-bottom. We will, however, only describe the first stage of operations, that is from the faces to the collecting-sidings or engine-siding. This haulage may be effected in various ways by men, boys, horses, ponies, etc., and where the inclination of the strata permits, by self-acting inclines. It may be done by one of these or by all. At the Hallbeath colliery, where the inclination varies from horizontal to about 45 degrees the headings are all driven to the rise.

This system permits of an arrangement which is universally adopted throughout Fife, termed the cut-chain arrangement, which forms one of the principal features of a Fife longwall working, and the writer is led to believe it was this arrangement partly which caused the remarks by H.M. inspector of mines, which he has already mentioned. It is worked as follows :—

(1) A wheel *A* is placed at the top of the heading, and is fitted up in the same manner as in an ordinary self-acting incline. The chain passes round the wheel, and down the heading to the foot of same. At every branch road or cut, as it is termed, a disconnecting-hook *B* is placed in the chain, so that the upper portion of the chain can be disconnected when required (Fig. 8, Plate VI.). Between the rails and across the breadth of the road deals or planks are fixed, so that a hutch can run right across the two roads of the incline. These planks or deals are fixed in so as not to interfere with the hutches coming down from the roads above. At the top of this platform is placed a small grooved wheel *C* and fixed firm to the platform (Fig. 9, Plate VI.). Whenever a hutch is required to be run down the incline from any of these cuts, the top portion of the chain is disconnected. The end of the lower portion of the chain is passed round the small wheel *C* at the top of the platform, and then fastened to the hutch. The hutch is then run down as in the ordinary incline. To brake this wheel while running, a small piece of wood about 18 inches long, of the shape of a pick shaft, is used, being pressed down on the top of the wheel while braking. In

working the top branch, the wheel *A* at the top of the heading is used, and acts in the same way as an ordinary incline.

The second arrangement is as follows :—A wheel *A* is fitted up at the top of the heading as in the first arrangement, but no wheels are used at the branch roads : the wheel at the top being made use of for the working of all the branches. The chain in this case, in addition to the length of the incline, must be as long as from the top of the incline down to the first branch. The chain will thus be twice the length of incline less the small distance from the level road to the first branch, and it is cut at every branch *B* (Fig. 10, Plate VI.). In the working of this arrangement, two hutches must be run from each branch every time, in order to get the cuts into their proper positions for the other branches to be able to work the same. The platforms at the branch-roads are the same as in the previous arrangement, and, where the inclination is steep, the pavement is cut out and the platform made level ; rails are then laid across the platform to allow the hutches to run across. These rails are not fastened down, but laid so that they may be lifted out at convenience when a branch road is being worked. In order to run a hutch from one of the branches, the lower portion of the short side of the chain is disconnected at the cut *B*. The upper portion is then fastened to the hutch and the hutch set away. The brake of the wheel at the top is operated by a wire attached to the brake-handle and led down the whole length of the incline. When the first hutch is run down, the empty hutch comes up the side away from the branch road. The second hutch is therefore run right across the incline to the farthest side, fastened to the chain and run down. The chain will then be in the position in which it was before running down the hutches. The drawer must then connect the two portions of chain again, so that the other branches may be allowed to make use of the incline. Care must be taken that the portions of the chain are all connected before the drawer leaves them.

The chain must be lifted from one side of the incline to the other side every time a hutch is run in the first arrangement, as the hutches are commonly only run down one side ; one hutch being taken from each branch at a time. Less chain is used in the first arrangement, but more wheels. Both systems are common in the district.

The hutches may be drawn from the faces to these inclines by the miners themselves, or it may be done by contract. Some managers think that by getting the miners to draw the coal to these inclines and run them themselves less time is wasted. When such is the case, there are two men and sometimes three men in each face, one being employed filling

the coal and drawing it, while the other is kept constantly at the face. In the other case, the coal is drawn from the face, after being filled by the miner, to the inclines, run down the inclines and drawn from the foot of the inclines to the engine-siding by contract: the contractor being paid by the score or by the ton.

The following is given as an example of this contract system in a section of the Jersey seam:—From the coal-face to the cut-chain brae two men are employed drawing; from the bottom of the cut-chain brae to the siding of the main haulage-road one boy is employed; the wages for one fortnight are £7 10s.; adding to this amount the keep and harness, etc., for one pony, £1 10s., making a total cost of £9. The total tonnage drawn from this section was 628·15 tons of coal and dross, showing a cost of 3·43d. per ton. The average distance along which each ton of coal was drawn was about 480 to 510 feet. The upkeep of chains and wheels, and veterinary attendance is not included. The cost of horse-keep is higher than the average allowance for keep of horses. The cost of haulage by men and horses is sometimes considerably higher than the above cost.

Another example of drawing in the same pits in the Dunfermline Splint seam is as follows:—From the coal-face down two cut-chain braes, six men and one boy are employed, the wages earned per fortnight being £19 17s. 1d., adding cost of keep of pony £1 10s., the total cost being £21 7s. 1d. The total quantity drawn from this section was 756·8 tons of coal and dross, making a cost of 6·77d per ton. The average distance per ton of coal drawn was about 900 feet to the engine-siding.

In one or two cases, where the drawing-road at places and for short distances in the same is rather steep for hand-putting yet not quite steep enough for a self-acting incline, an arrangement on the same principle as the incline is used. At the side of the drawing-road, another road of a narrow gauge is laid down the whole length of the road where the steepness occurs. A small loaded bogie is put on this road. A wheel is fixed at the top of the steep part of the road, and a chain is passed round this wheel and fastened to the bogie. When the drawer comes to this part of the road with his loaded hutch, he fastens the loose end of the chain to his hutch and the loaded hutch in going down this small incline draws up the bogie. The loaded hutch may not of itself be able to draw up the bogie, and the drawer has then to push the loaded hutch down. After reaching the bottom, the chain is made fast to some catch so as to prevent the bogie from running back. When the drawer returns with the empty hutch, he fastens the chain to it, and the drawer is thus assisted by the counterbalance to the top of the steepness. By inverting the arrange-

ment and making the bogie a little heavier it can be used to assist in drawing the loaded hutch up a small dook where the drawer is not able to do the same himself.

Ventilation.—By ventilation, we mean the removal of all dangerous and deleterious gases from the mine, or the rendering of such gases harmless, so as to keep the mine in a safe and healthy condition. In accordance with the Coal Mines Regulation Act, an adequate amount of ventilation must be constantly produced, so that the working-places and travelling roads to and from these places may be in a fit state for working therein. The quantity of air passing in the various splits and airways must be measured every month, and a note of the same entered in a book kept for such purpose at the mine. The ventilation must also be inspected every morning before the miners begin work, and such inspection noted in the aforesaid book. The airways must be not less than 4 feet high and 4 feet wide and must always be in a fit state for travelling therein.

The gases generally found in mines which are of a dangerous nature are light carburetted hydrogen (fire-damp), sulphuretted hydrogen, carbon dioxide or carbonic acid gas, and carbon monoxide. These are the chief gases met with which endanger life and property. In this district, there is practically no fire-damp or carbon monoxide. There is abundance of carbon dioxide or carbonic acid generally called choke-damp or black-damp.

Sulphuretted hydrogen is very seldom found. On one occasion, the writer came in contact with a small trace at the side of a roadway where some small coal was lying and the pyrites in the same was being decomposed by the water running at the side of the roadway. On the small coal being disturbed, the gas was soon dispelled.

Choke-damp or black-damp is given off in great quantities from the workings in this district, and being very heavy it lies near to the floor of the mine and is not easily shifted. In one instance, when a section of one of the seams in the Kingseat pits had been flooded with water and then had not been worked for a few weeks, it was found that the section was full of choke-damp, and it had accumulated to such an extent that some weeks elapsed before it was all got out.

In ventilating in this district, the air is first conducted to the dip-workings and from thence to the rise portions.

The return portions of the airways are generally of smaller diameter or sectional area than the intakes, and this causes the current to travel at a high velocity. A slow current of air would only flow over the top of the choke-

damp and leave it lying on the floor, and by making the return-airways of small area, the stronger current is able to push this gas along and so get rid of it.

The ventilation at all the collieries in this district is produced by fans of the Waddle, Guibal, or Schiele types, practically no furnaces being in operation. At the Kingseat colliery, a Guibal exhausting fan, 24 feet in diameter by 8 feet broad, is employed to ventilate three shafts, and a Schiele exhausting fan, 40 inches in diameter, is used to ventilate one shaft. The following is a note of the various quantities produced and passing in the various airways :—

		No. of Split.	Smallest Area. Square Feet.	Length of Airway. Feet.	Quantity of Air. Cubic Feet per Minute.
No. 1 shaft	...	1	24	8,310	7,800
		2	22	8,985	6,500
		3	16	3,000	2,000
No. 2 shaft	...	1	28	12,894	7,100
		2	24	8,400	3,900
		3	20	6,150	2,800
No. 3 shaft	...	1	25	4,410	6,500
		2	24	3,390	5,300
No. 4 shaft	...	1	20	4,300	2,800

The total quantity circulated by the Guibal fan being 41,900 cubic feet per minute, and by the Schiele fan 2,800 cubic feet per minute.

In the ventilation of the Jersey seam, the air is conducted up the heading and split at the top, one half of the current going round the faces of the first working and the other half round the faces of the second working (Fig. 1, Plate VI.). Where the second line of faces are following up behind the first working, a regulator is sometimes put in halfway between the faces of the first working and the faces of the second working, and so causes part of the current to be passed round each set of faces.

References to Plate VI.

Fig. 1 is a plan of workings in the Jersey seam.

Fig. 2 is a plan of the face of the first working, showing the pack-walls and road.

Fig. 3 is a section of the face of the first working, with the strata comprising the same.

Fig. 4 is a section of a roadway in the first working.

Fig. 5 is a plan of the face of the second working.

Figs. 6 and 7 are sections of the face of the second working.

Fig. 8 is a plan of a cut-chain brae. *C* is a small wheel for working the cuts, and *B* the cut hook or disconnecting-link.

Fig. 9 shows the form of wheel used at the branch-roads.

Fig. 10 is a plan of a cut-chain brae as used in the second arrangement.

Fig. 11 shows the cut hook or disconnecting-link.

Fig. 12 is a section of a platform at a branch road.

APPENDIX A.—SECTION OF STRATA IN THE WESTERN DISTRICT OF FIFESHIRE BELOW THE MILLSTONE GRIT.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth Below Millstone Grit. Ft.	In.
	Millstone Grit, composed principally of rough sandstones ...	773	0		
	Levenseat or Castlecary Limestone—				
1	Limestone ...	7	0	7	0
2	Shale	7	0	14	0
3	Limestone ...	2	0	16	0
4	Shale	6	0	22	0
5	**COAL**, in bands and shales ...	3	0	25	0
6	Sandstone	5	0	30	0
7	Shale	4	0	34	0
8	Sandstone	64	0	98	0
9	Shale	3	0	101	0
10	Sandstone	2	0	103	0
11	Shale	3	0	106	0
12	**COAL**	0	4	106	4
13	Sandstone and bands	6	0	112	4
14	Shale	6	2	118	6
15	**COAL**	0	6	119	0
16	Fireclay	6	3	125	3
17	Shale	4	6	129	9
18	Sandstone	4	0	133	9
19	Shale and bands ...	5	6	139	3
20	Shale	2	0	141	3
21	**COAL**	0	2	141	5
22	Sandstone	9	10	151	3
23	Shale	2	11	154	2
24	**COAL**	0	10	155	0
25	Shale	3	0	158	0
26	Sandstone	2	6	160	6
27	Shale	6	0	166	6
28	Sandstone	20	0	186	6
29	**COAL**	0	4	186	10
30	Shale and bands, with ironstone-nodules	6	0	192	10
31	**COAL**	0	4	193	2
32	Shale	0	9	193	11
33	**COAL**	0	3	194	2
34	Shale	0	9	194	11
35	**COAL**	0	4	195	3
36	Shale	1	0	196	3
37	Sandstone	7	10	204	1
38	Shale	4	9	208	10
39	Sandstone and bands	3	0	211	10
40	Shale	3	0	214	10
41	Bituminous shale ...	10	6	225	4
42	Bands	4	2	229	6
43	Fireclay	2	0	231	6
44	**COAL**	0	6	232	0
45	Shale	2	0	234	0
46	Sandstone	6	6	240	6
47	**COAL**	0	4	240	10
48	Bands and shale ...	17	0	257	10
49	Sandstone	38	0	295	10
50	Alum shale... ...	17	3	313	1
	Gair or Calmy Limestone—				
51	Limestone ...	0	8	313	9
52	Shale	0	7	314	4
53	Limestone ...	1	8	316	0
54	Alum shale... ...	8	0	324	0
55	Sandstone	4	9	328	9
56	Bands and shale ...	19	0	347	9
57	Sandstone	11	0	358	9
58	Bands and shale ...	14	0	372	9
59	Shale	22	0	394	9
60	Shale and bands ...	22	6	417	3
61	Bands and sandstone	88	11	506	2
	Capledrae Parrot Coal-seam—				
62	**COAL**	4	4	510	6
63	Fireclay	4	0	514	6
64	Oil-shale	2	6	517	0
65	Fireclay and faikes	30	7	547	7
66	**COAL**	2	5	550	0
67	Faikey fireclay ...	15	0	565	0
68	Blaes	2	0	567	0
69	Blackband ironstone	0	9	567	9
70	Fireclay	0	4	568	1
71	Blackband ironstone	0	4	568	5
72	Fireclay	0	6	568	11
73	Faikey sandstone ...	25	1	594	0
74	**COAL**	1	0	595	0
75	Bands and sandstone	25	0	620	0
76	**COAL**	1	0	621	0
77	Sandstone	34	2	655	2
78	**COAL**	0	10	656	0
79	Sandstone	181	0	837	0
80	**COAL**	1	0	838	0
81	Faikes and fireclay	11	10	849	10
82	**COAL**, *Lochore Parrot Coal-seam* ...	2	2	852	0
83	Faikes and sandstone	18	0	870	0
84	**COAL**, *Bowersbank Splint Coal-seam*	3	0	873	0
85	Sandstone with thin *coal-seams* ...	46	0	919	0
86	Sandstone	93	6	1,012	6
87	Faikes	15	3	1,027	9
88	Limestone, *Index* ...	2	3	1,030	0

APPENDIX A.—*Continued.*

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth Below Millstone Grit. Ft.	In.
89	Sandstone	31	9	1,061	9
90	Fireclay with balls	11	6	1,073	3
91	Sandstone	17	6	1,090	9
Comrie and Balbardie Coal-seam—					
92	**COAL**, rough ...	1	4	1,092	1
93	**COAL**, parrot ...	0	9	1,092	10
94	Blackband ironstone	0	8	1,093	6
95	Blaes	1	0	1,094	6
96	Faikes and sandstone	40	6	1,135	0
97	**COAL**, *Blairhall Coal-seam* ...	4	0	1,139	3
98	Sandstone	24	3	1,163	0
99	**COAL**, *Blairhall Coal-seam* ...	4	3	1,167	6
100	Sandstone and faikes	9	6	1,177	0
101	**COAL**, *Soft Smithy Coal-seam* ...	3	0	1,180	0
102	Sandstone	34	0	1,214	0
103	Fireclay with balls	4	9	1,218	9
104	Ironstone, *Lochgelly Blackband* ...	2	3	1,221	0
105	Fireclay and bands	10	0	1,231	0
106	**COAL**	0	3	1,231	3
107	Blaes and bands ...	17	6	1,248	9
108	Sandstone	10	9	1,259	6
109	Blaes and bands ...	14	3	1,273	9
110	**COAL**	0	6	1,274	3
111	Bands and freestone	61	6	1,335	9
112	**COAL**, *Little Splint Coal-seam* ...	4	3	1,340	0
113	Bands	5	0	1,345	0
114	Freestone	4	9	1,349	9
115	Bands	5	11	1,355	8
116	**COAL**, *Rough Coal-seam*	3	4	1,359	0
117	Bands	11	6	1,370	6
118	**COAL**, *Main Coal-seam*	3	0	1,373	6
119	Fireclay	4	2	1,377	8
120	**COAL**	1	4	1,379	0
121	Freestone	2	0	1,381	0
Jersey Coal-seam—					
122	Blaes and bands	9	6	1,390	6
123	**COAL**	2	4	1,392	10
124	Blaes and bands	1	0	1,393	10
125	**COAL**	3	7	1,397	5
126	Fireclay ...	2	1	1,399	6
127	**COAL**	3	6	1,403	0
128	Blaes	0	6	1,403	6
129	Fireclay	1	3	1,404	9
130	Bands	9	6	1,414	3
131	Blaes	2	0	1,416	3
132	**COAL**, *Swallowdrum Coal-seam* ...	4	9	1,421	0
133	Bands	1	10	1,422	10
134	Fireclay	3	9	1,426	7
135	Bands	15	3	1,441	10
136	Fireclay	2	6	1,444	4
137	Bands	0	9	1,445	1
138	Fireclay	2	10	1,447	11
139	Bands	12	9	1,460	8
140	**COAL** and blaes ...	1	9	1,462	5
141	Bands and blaes ...	8	7	1,471	0
142	**COAL**, *Duddy Davie Coal-seam* ...	3	0	1,474	0
143	Blaes	2	3	1,476	3
144	Fireclay	1	0	1,477	3
145	Bands	3	10	1,481	1
146	Freestone	14	0	1,495	1
147	Fireclay	1	5	1,496	6
148	**COAL**, *Lochgelly Splint Coal-seam*	6	0	1,502	6
149	Blaes	4	0	1,506	6
150	Freestone	21	9	1,528	3
151	Blaes	2	3	1,530	6
152	**COAL**, *Lochgelly Parrot Coal-seam*	3	6	1,534	0
153	Grey bands... ...	8	0	1,542	0
154	Sandstone	20	0	1,562	0
155	Blaes and grey bands	37	0	1,599	0
156	Sandstone	2	9	1,601	9
157	Blaes	14	6	1,616	3
158	**COAL**, *Glassee Coal-seam*	2	9	1,619	0
159	Fireclay and blaes	5	0	1,624	0
160	Bands	5	9	1,629	9
161	Sandstone	59	0	1,688	9
162	Bands and blaes ...	21	2	1,709	11
163	Ironstone	0	4	1,710	3
164	**COAL**, *Mynheer Coal-seam* ...	3	3	1,713	6
165	Sandstone	12	0	1,725	6
166	Blaes	13	0	1,738	6
167	**COAL**	0	6	1,739	0
168	Fireclay	1	0	1,740	0
169	**COAL**	2	0	1,742	0
170	Bands	13	6	1,755	6
171	Sandstone	4	6	1,760	0
172	Blaes	1	0	1,761	0
173	Sandstone	4	0	1,765	0
174	Bands and blaes ...	12	4	1,777	4
175	**COAL**, *Five Feet Coal-seam* ...	4	8	1,782	0
176	Sandstone	2	0	1,784	0
177	Bands, with ironstone balls ...	54	6	1,838	6
178	Sandstone	39	0	1,877	6
179	Dark bands ...	1	9	1,879	3
180	**COAL**, *Dunfermline Splint Coal-seam*	3	9	1,883	0
181	Sandstone	14	0	1,897	0
182	Blaes	8	0	1,905	0
183	Freestone	5	6	1,910	6
184	Freestone with blaes	20	0	1,930	6
185	Blaes	20	3	1,950	9
186	**COAL**, *Stinking Coal-seam* ...	1	3	1,952	0
187	Sandstone and blaes	128	0	2,080	0
188	Limestone, *Hosie Limestone* ...	3	0	2,083	0

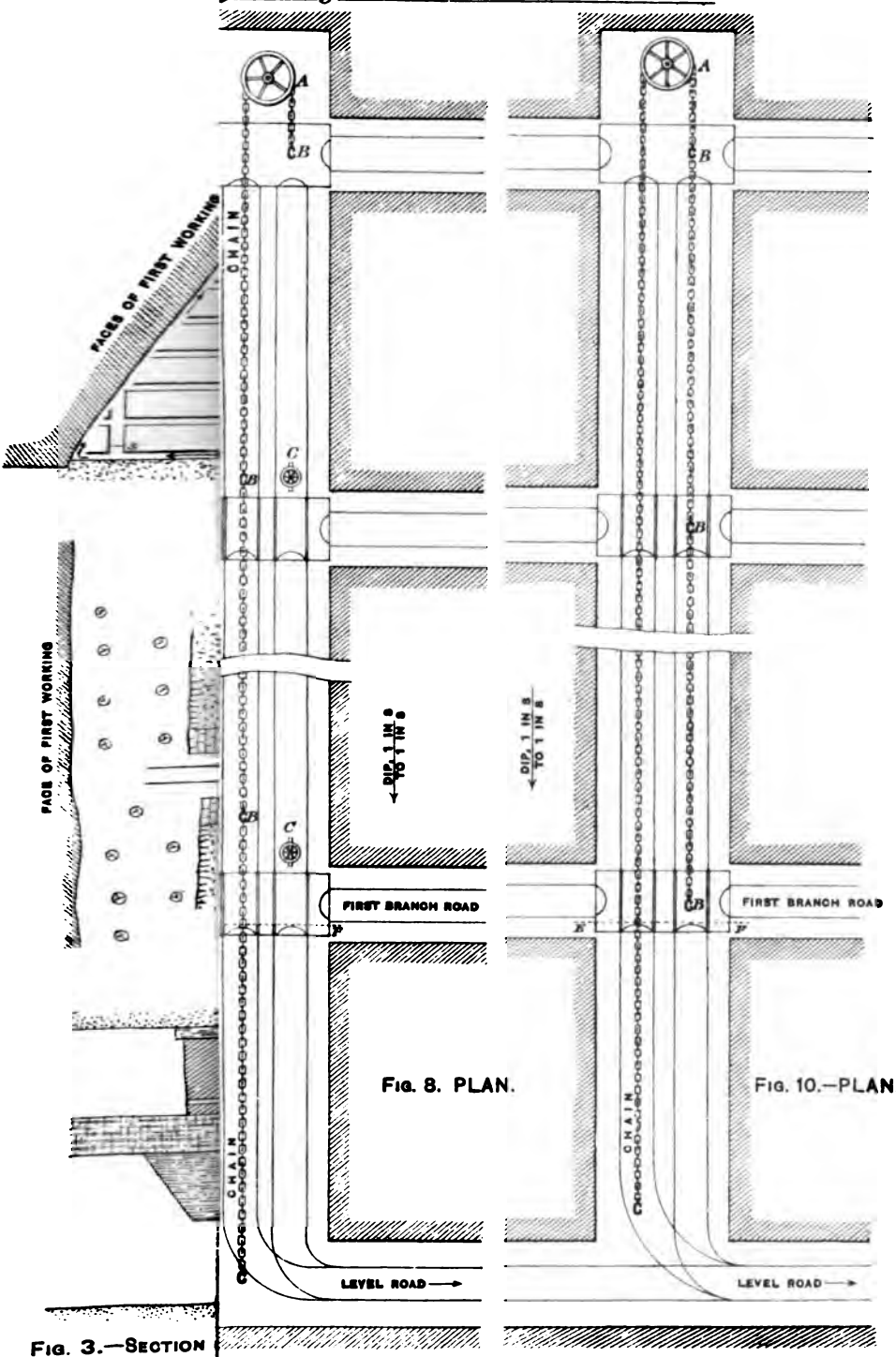

Fig. 8. PLAN.

Fig. 10.—PLAN.

Fig. 3.—Section Jere

Fig. 12.—Section of Platform through E F on Figs. 8 and 10.

APPENDIX A.—*Continued.*

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth Below Millstone Grit. Ft.	In.
89	Sandstone	31	9	1,061	9
90	Fireclay with balls	11	6	1,073	3
91	Sandstone	17	6	1,090	9
Conrie and Balbardie Coal-seam—					
92	**COAL**, rough ...	1	4	1,092	1
93	**COAL**, parrot ...	0	9	1,092	10
94	Blackband ironstone	0	8	1,093	6
95	Blaes	1	0	1,094	6
96	Faikes and sandstone	40	6	1,135	0
97	**COAL**, *Blairhall Coal-seam* ...	4	0	1,139	3
98	Sandstone	24	3	1,163	0
99	**COAL**, *Blairhall Coal-seam* ...	4	3	1,167	6
100	Sandstone and faikes	9	6	1,177	0
101	**COAL**, *Soft Smithy Coal-seam* ...	3	0	1,180	0
102	Sandstone	34	0	1,214	0
103	Fireclay with balls	4	9	1,218	9
104	Ironstone, *Lochgelly Blackband* ...	2	3	1,221	0
105	Fireclay and bands	10	0	1,231	0
106	**COAL**	0	3	1,231	3
107	Blaes and bands ...	17	6	1,248	9
108	Sandstone	10	9	1,259	6
109	Blaes and bands ...	14	3	1,273	9
110	**COAL**	0	6	1,274	3
111	Bands and freestone	61	6	1,335	9
112	**COAL**, *Little Splint Coal-seam* ...	4	3	1,340	0
113	Bands	5	0	1,345	0
114	Freestone	4	9	1,349	9
115	Bands	5	11	1,355	8
116	**COAL**, *Rough Coal-seam*	3	4	1,359	0
117	Bands	11	6	1,370	6
118	**COAL**, *Main Coal-seam*	3	0	1,373	6
119	Fireclay	4	2	1,377	8
120	**COAL**	1	4	1,379	0
121	Freestone	2	0	1,381	0
Jersey Coal-seam—					
122	Blaes and bands	9	6	1,390	6
123	**COAL**	2	4	1,392	10
124	Blaes and bands	1	0	1,393	10
125	**COAL**	3	7	1,397	5
126	Fireclay ...	2	1	1,399	6
127	**COAL**	3	6	1,403	0
128	Blaes	0	6	1,403	6
129	Fireclay	1	3	1,404	9
130	Bands	9	6	1,414	3
131	Blaes	2	0	1,416	3
132	**COAL**, *Swallowdrum Coal-seam* ...	4	9	1,421	0
133	Bands	1	10	1,422	10
134	Fireclay	3	9	1,426	7
135	Bands	15	3	1,441	10
136	Fireclay	2	6	1,444	4
137	Bands	0	9	1,445	1
138	Fireclay	2	10	1,447	11
139	Bands	12	9	1,460	8
140	**COAL** and blaes ...	1	9	1,462	5
141	Bands and blaes ...	8	7	1,471	0
142	**COAL**, *Duddy Davie Coal-seam* ...	3	0	1,474	0
143	Blaes	2	3	1,476	3
144	Fireclay	1	0	1,477	3
145	Bands	3	10	1,481	1
146	Freestone	14	0	1,495	1
147	Fireclay	1	5	1,496	6
148	**COAL**, *Lochgelly Splint Coal-seam*	6	0	1,502	6
149	Blaes	4	0	1,506	6
150	Freestone	21	9	1,528	3
151	Blaes	2	3	1,530	6
152	**COAL**, *Lochgelly Parrot Coal-seam*	3	6	1,534	0
153	Grey bands... ...	8	0	1,542	0
154	Sandstone	20	0	1,562	0
155	Blaes and grey bands	37	0	1,599	0
156	Sandstone	2	9	1,601	9
157	Blaes	14	6	1,616	3
158	**COAL**, *Glassee Coal-seam*	2	9	1,619	0
159	Fireclay and blaes	5	0	1,624	0
160	Bands	5	9	1,629	9
161	Sandstone	59	0	1,688	9
162	Bands and blaes ...	21	2	1,709	11
163	Ironstone	0	4	1,710	3
164	**COAL**, *Mynheer Coal-seam* ...	3	3	1,713	6
165	Sandstone	12	0	1,725	6
166	Blaes	13	0	1,738	6
167	**COAL**	0	6	1,739	0
168	Fireclay	1	0	1,740	0
169	**COAL**	2	0	1,742	0
170	Bands	13	6	1,755	6
171	Sandstone	4	6	1,760	0
172	Blaes	1	0	1,761	0
173	Sandstone	4	0	1,765	0
174	Bands and blaes ...	12	4	1,777	4
175	**COAL**, *Five Feet Coal-seam* ...	4	8	1,782	0
176	Sandstone	2	0	1,784	0
177	Bands, with ironstone balls ...	54	6	1,838	6
178	Sandstone	39	0	1,877	6
179	Dark bands ...	1	9	1,879	3
180	**COAL**, *Dunfermline Splint Coal-seam*	3	9	1,883	0
181	Sandstone	14	0	1,897	0
182	Blaes	8	0	1,905	0
183	Freestone	5	6	1,910	6
184	Freestone with blaes	20	0	1,930	6
185	Blaes	20	3	1,950	9
186	**COAL**, *Stinking Coal-seam* ...	1	3	1,952	0
187	Sandstone and blaes	128	0	2,080	0
188	Limestone, *Hosie Limestone* ...	3	0	2,083	0

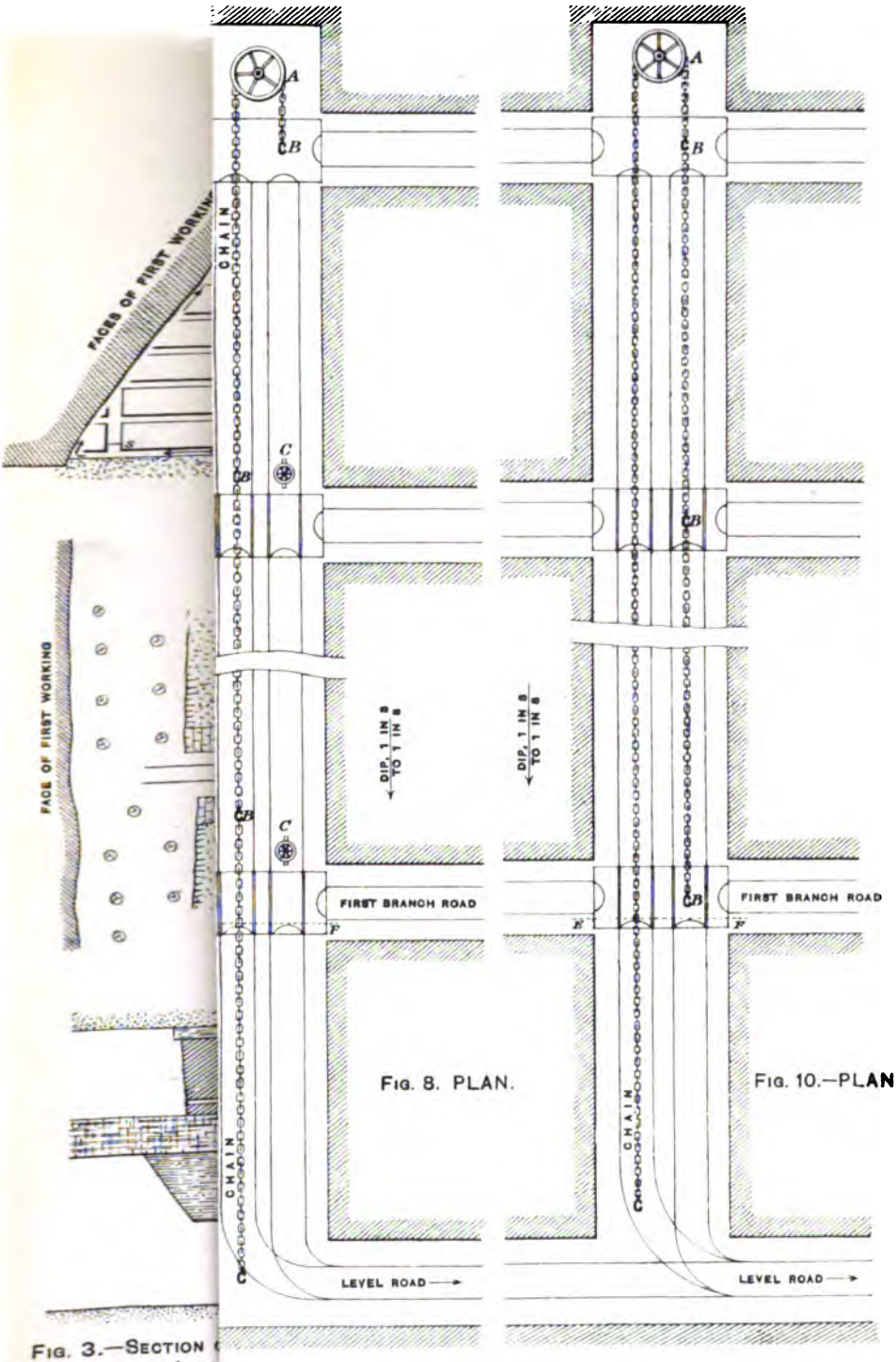

Fig. 8. PLAN.

Fig. 10.—PLAN.

Fig. 3.—Section ... Jers...

Fig. 12.—Section of Platform through E F on Figs. 8 and 10.

APPENDIX B.—Section of the Jersey Coal-seam.

	Ft.	In.	Ft.	In.
Roof—				
Sandstone	8	8		
			8	8
Second Working—				
Blaes	0	4		
COAL	2	4		
Stone	0	2		
COAL	0	5		
			3	3
Bands—Fire-clay	1	4		
			1	4
First Working—				
Blaes and bands ...	2	6		
COAL	2	2		
Fire-clay	0	11		
			5	7
Floor—				
Sandstone	12	4		
			12	4

APPENDIX C.—Section of the Lochgelly Splint and Parrot Coal-seam.

	Ft.	In.	Ft.	In.
Roof—Blaes	—		—	
Second Working—				
COAL	1	6		
Coaly strains	0	5		
Faikey blaes	0	11		
Coaly blaes	0	2		
COAL, with varying layers of stone ...	3	4		
Rib	0	1		
COAL	0	4		
			6	9
Bands—				
Blaes	3	0		
Sandstone	0	6		
Fire-clay	3	0		
COAL	0	4		
			6	10
First Working—				
Bands	2	0		
Fallen	0	1		
COAL, with varying layers of stone ...	2	2½		
Rib	0	0½		
COAL	0	5		
Rib	0	1		
COAL	1	7		
			6	5
Floor—Sandstone	—		—	

Mr. Harry Rhodes said that the Students were indebted to Mr. Burt for a very interesting paper. With regard to stoop-and-room working, the writer seemed to find that they made larger coal in the bords than in the ends. This was the reverse of his (Mr. Rhodes') experience at collieries in Yorkshire. In some experiments made recently, bord-places produced 52 per cent. of large coal, and end-places 80 per cent. If there was any heading-out or cross-cutting, the percentage of large coal was reduced to 65.

The cost of horse-keep seemed to be high, as in Yorkshire it was about 8s. 2d. per week for feeding and grooming.

Mr. T. E. Parrington remarked that if the top stone were brushed a "second" time, it was rather costly. The writer stated that all thick seams of "minerals" could be worked by the longwall system. This was rather vague, and he did not suppose it would be possible to work by longwall an ironstone-seam 9 feet thick, such as they had in Cleveland.

Mr. A. BURT said that the thick seams generally contained one or two thinner seams of sandstone, as shown in the Appendices. The distance between the headings of the bords in the stoop-and-room working varied from 90 to 150 feet.

Mr. HARRY RHODES said that at Denaby and Cadeby collieries, in South Yorkshire, a 10½ feet coal-seam was worked by longwall in one operation.

Mr. T. E. PARRINGTON referred to the statement that in ventilating a district the air was first conducted to the dip-workings and thence to the rise-workings. If there was a large quantity of choke-damp, it would probably collect in the dip-workings, and if these dip-workings were ventilated first the tendency would be to carry the choke-damp into the rise-workings.

Mr. HARRY RHODES said that the regulations for many Continental coal-mines required that the ventilation should be ascentional, viz. :— that the air should pass uphill all the way to the highest point of the workings, and thence into the upcast shaft.

Mr. A. BURT said that the ventilating-current was split into two or more divisions as required, and the choke-damp was removed by a special current.

The CHAIRMAN (Mr. H. W. Middleton) asked how far (in the stoop-and-room working) were the whole workings kept from the broken ?

Mr. A. BURT said that he thought the average distance was about 300 feet or so.

Mr. T. E. PARRINGTON said it appeared from the paper that the stoop-and-room system was adopted where special precautions were necessary to prevent damage to buildings, etc., on the surface. He supposed that the stoop-and-room was practically the same as the bord-and-pillar system : he knew cases where the bord-and-pillar system had been the general method, except under buildings where longwall had been substituted. The idea being that, by removing the coal as fast as possible, a more even subsidence took place.

Mr. A. BURT remarked that the proprietors and landlords generally put clauses into the leases as to whether coal was to be worked on the longwall or stoop-and-room systems.

The CHAIRMAN moved a vote of thanks to Mr. Burt for his paper, in which he had gone very thoroughly into his subject. He (the

Chairman) had also the pleasure of presenting to the writer of the paper the prize of books, which had been awarded to him by the Institution.

Mr. ALGERNON NOBLE moved, and Mr. HENRY D. COWAN seconded, a vote of thanks to Mr. H. W. Middleton for his services in the chair, which was agreed to.

The meeting was then closed.

The Ashington, Saint Hilda, Wallsend, and Whitburn collieries were opened to the inspection of visitors during the course of the meeting on August 18th, 19th, and 20th, 1897.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, OCTOBER 18TH, 1897.

MR. JOEL SETTLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBER—

Mr. WILLIAM WOODALL, M.P., Colliery Proprietor, Bleak House, Burslem.

ASSOCIATE—

Mr. PAUL EDWARDS, Underviewer, Talk-o-'th'-Hill Colliery, Stoke-upon-Trent.

STUDENT—

Mr. JOHN MILNES FAVELL, Mining Student, Heatherlea, Wolstanton, Stoke-upon-Trent.

The annual report of the Council was read as follows :—

ANNUAL REPORT OF THE COUNCIL.

The Council of the Institute have pleasure in presenting their Annual Report ; the membership shows a small increase on that of the past year, although the classification of members is slightly different.

The following is a comparative summary of the past two years :—

	Year 1895-96.	Year 1896-97.
Honorary Members	6	6
Life Member	1	1
Members	119	116
Associate Members	3	5
Associates	35	36
Students	16	19
	180	183

Five Members, 3 Associate Members, 4 Associates and 4 Students have been elected during the year. The total retirements from all causes are 13, viz. :—Resignations, Members, 6 ; Associate Member, 1 ; Associates, 2 ; and 4 by death : Messrs. Wm. Bridget, Alfred Jackson, Robert Lucas, and Thomas Robinson. One Member has been transferred to the class of Associates and one Student to the class of Members.

General Meetings have been held in the months of September, October (Annual), December, January, March, May, July, and September (Special).

The following valuable papers have been communicated :—

"The Steam-turbine Engine." By Mr. John D. Bailie.
"Improved Safety-lamp." By Mr. Jno. Gregory.
"Cheshire Salt-district." By Mr. C. E. de Rance.
"Notes on Water-supply." By Mr. C. E. de Rance.
"South Wales and Lancashire Coal-fields." By Mr. C. E. de Rance.
"The Kent Coal-field." By Mr. C. E. de Rance.
"Presidential Address." By Mr. Joel Settle.
"Improved Apparatus for Drawing Timber in Mines." By Mr. E. B. Wain.

The meetings, the Council regret to say, have not been so well attended as they would have desired, and they ask for the more hearty co-operation of the members in the future.

Considerable advantages are undoubtedly obtained by our affiliation with The Federated Institution of Mining Engineers, which Institution now comprises the following Societies :—The Chesterfield and Midland Counties Institution of Engineers ; The Midland Institute of Mining, Civil, and Mechanical Engineers ; The Mining Institute of Scotland ; The North of England Institute of Mining and Mechanical Engineers ; The North Staffordshire Institute of Mining and Mechanical Engineers ; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The following table illustrates the progress of that Institution since its formation on July 1st, 1889 :—

Year.	No. of Members.	No. of Non-Federated.	Totals.
1889-90	1,189	50	1,239
1890-91	1,187	9	1,196
1891-92	1,415	19	1,434
1892-93	1,533	19	1,552
1893-94	2,068	123	2,191
1894-95	2,210	109	2,319
1895-96	2,301	81	2,382
1896-97	2,434	60	2,494

The Annual Meeting of The Federated Institution of Mining Engineers was held in September, 1896, at Cardiff. The other meetings were held in February, at Manchester, and in June at London.

The papers printed in the *Transactions* comprise the following :—

	No. of Papers
Geology	25
Mining engineering and safety-appliances	19
Mechanical engineering	12
Colliery explosions, coal-dust, safety-lamps, and mine ventilation	8
The preparation of minerals	2
Explosives and blasting	4
Electricity and its applications	2
Metallurgy	2
Miscellaneous papers	11
Total	85

The preceding list demonstrates the varied nature of the communications printed in the *Transactions* during the past year, and valuable discussions have arisen on subjects of special interest.

Prizes have been awarded to the writers of four papers in the *Transactions*, vols. x. and xi., for the year 1895-96, and with pleasure we notice that one has been obtained by Mr. C. E. de Rance, a member of this Institute, for his paper on "The Depth to Productive Coal-measures between the Warwickshire and Lancashire Coal-fields."

Your Council refer with much pleasure to the work done under the direction of the Technical Instruction Committee of the Staffordshire County Council, in which the Council and Members of this Institute have always taken a keen interest. The Examination for Mining Studentships was held at Stoke-upon-Trent, May 1st, 1897, the examiners being Colonel Strick and Mr. Edward B. Wain, both Past-Presidents of this Institute, when the following awards were made :—3 Studentships of £3 each ; 5 of £2 each ; 17 of £1 each ; 2 Book Prizes of 10s. each ; 4 of 7s. 6d. each ; and 5 of 5s. each. Several of the recipients were students of this Institute. One of the £30 Scholarships was gained by Mr. John Cadman, son of one of our oldest members ; and the other by Mr. Share, a working miner in South Staffordshire, thus proving the great benefit that can be derived by all who attend these classes. The prizes were distributed by Mr. William Woodall, M.P., at a public meeting held in the Town Hall, Stoke-upon-Trent, on September 11th, Mr. Edward B. Wain occupying the chair, and many members of the Institute were present.

It is proposed to hold, during the winter months, classes or lectures of a higher grade in conjunction with this Institute, and the County

Council have promised to support the same, both pecuniarily and otherwise. It is sincerely hoped that one and all will use their utmost endeavours to make these courses a perfect success, and so promote the usefulness of the Institute.

ANNUAL REPORT OF THE FINANCE COMMITTEE.

The Finance Committee have pleasure in reporting that the expenditure has been £44 16s. 11d. less than the income, the total receipts for the year being £310 19s. 6d., as against £323 7s. in 1896. The credit balance in the bank on July 31st, 1897, was £183 10s., as against £138 13s. 1d. last year. The arrears of subscriptions (although each member has had four notices of his indebtedness) still amount to £118 11s. 6d., as against £164 9s. last year.

The reports were adopted.

ELECTION OF OFFICERS, 1897-98.

PRESIDENT.
Mr. JOEL SETTLE.

VICE-PRESIDENTS.
Mr. J. C. CADMAN. | Mr. H. R. MAKEPEACE. | Mr. J. J. PREST.

TREASURER.
Mr. H. R. MAKEPEACE.

SECRETARY.
Mr. J. RICHARD HAINES.

COUNCIL.

Mr. W. N. ATKINSON.	Mr. JAMES MADDOCK.
Mr. THOMAS M. FAVELL.	Mr. JOHN NEWTON.
Mr. JOHN HEATH.	Mr. C. E. DE RANCE.
Mr. A. M. HENSHAW.	Mr. FRANK RIGBY.
Mr. GEO. P. HYSLOP.	Mr. FREDK. SILVESTER.
Mr. GEO. E. LAWTON.	Mr. THOMAS E. STOREY.

THE PRESIDENT (Mr. Joel Settle) delivered the following address :—

PRESIDENTIAL ADDRESS.

By Mr. JOEL SETTLE.

I have again to thank the members for appointing me President of this Institute for the coming year. I have much pleasure in accepting this honour, and wish to express my thanks to the Council and Secretary for the valuable assistance which they have rendered, and to the members generally for their cordial support. I do not propose to trouble you with a long address, but there are a few subjects of interest on which I will say a few words.

Explosives Order.—The order of the Home Secretary under the Coal Mines Regulation Act, 1896, will undoubtedly add to the cost of producing coal from most mines, but on the other hand it may fairly be hoped that it will increase safety in fiery and dusty mines, and as the use of the permitted explosives is already so largely established in this district the effect of the order will probably not be so onerous here as in other districts. The modifications introduced into the amended order removed many of the objections made to the order as originally framed. It is gratifying to note that the work of the various committees in this and other districts has led to this improvement.

With the increased use of safety-explosives, it is hoped that the terrible disasters which have marked the history of coal-mining will become things of the past, although it will be necessary that greater care should be taken in the handling and use of the more powerful explosives. Although the Home Secretary's order cannot be regarded as an ideal code of regulations, either by the advocates of the total abolition of gunpowder in mines or by those who contend that gunpowder may safely be used in many coal-mines; yet, when we consider the difficulties in framing an order to meet the varied and complicated conditions encountered in the working of collieries, we must accept the order as an earnest attempt to prevent the disastrous explosions which have been too frequent in the past, and I feel sure that the members of this Institute will do their best to comply with the order for this desirable purpose. It is greatly to be feared that the use of permitted explosives will reduce the proportion of large coal, and we still wait for the introduction of an explosive which will combine the safety of the permitted explosives with the economy of

gunpowder. There are a large number of safety-explosives on the market, but none of them so suitable as gunpowder for the purpose of coal-mining, owing to their high power and shattering action.

Workmen's Compensation Act, 1897.—It is to be regretted that legislation on this subject has been so hurriedly passed without allowing time for a full consideration of the subject by the parties interested. It appears doubtful whether what were stated to be two of the most important objects of the promoters of the Act will be attained, viz., the prevention of litigation and the preservation of the existing friendly and relief societies. Whether an accident "is attributable to the serious and wilful misconduct" of a workman is certain in many cases to be a matter of dispute; and, although elaborate provisions are made for the settlement of claims by arbitration, this is really a species of litigation liable to be as vexatious as ordinary legal proceedings.

Provision is made in the act for "schemes of compensation" which in the case of mining industry might under altered conditions include the permanent relief societies, but the attainment of the required conditions appears to bristle with difficulties. No direct pecuniary benefit can be obtained by employers by subscribing to such schemes, and it bodes ill for the preservation of mutual societies that the directors of the great firm of Sir W. G. Armstrong, Whitworth, & Co., Limited, have decided to terminate the contribution of the firm to the relief society connected with their works. Nevertheless, it would be a great misfortune if the miners' permanent relief societies were destroyed by this act, and I think that the effort should be made to preserve them for the mutual advantage of employers and workmen. The advantages to colliery-owners would be that at a cost estimated to be the same as that which they would have to bear in any case, they would be relieved of all trouble in settling the claims arising under the Act; and by the co-operation of the miners in contributing to, and assisting in the management of the funds, they would secure valuable aid in the prevention of malingering and unfounded claims, and in addition, the friendly relations which should always exist between employers and employed would be better maintained. The advantages to the miners would be that by contributing to the fund they would have a share in the management and obtain additional benefits to these conferred by the Act. These additional benefits might comprise compensation for accidents not causing disablement for more than 2 weeks, and compensation during the first 2 weeks in cases where the disablement exceeded that period. It might also be provided that compensation

should be paid for accidents which are excluded by the Act. For instance, if a miner was killed by his own "serious and wilful misconduct," such as in an extreme case the unramming of a shot, his widow or other dependent relatives would have no claim for compensation under the Act, although their case might be as worthy of alleviation as if the husband had been killed by an accident entirely beyond his own control. These and possibly other extra benefits, which might be arranged for, would be of great advantage to the miners. If some scheme such as that above indicated be not arranged, colliery-owners will be bound to insure their liabilities under the Act, and the policy of insurance companies will be to contest all the claims they possibly can.

Increased Output.—Last year, the total output for Great Britain exceeded 195,000,000 tons, the highest output yet recorded; and this was almost 6,000,000 tons more than the previous year. It is noteworthy that although there was so marked an increase in the output there was a reduction in the number of persons employed in the coal-mines. It is not clear how this variation is to be accounted for; it may be largely due to more days being worked in the latter year; and contributing causes may be that the unremunerative conditions under which the coal-trade has recently been carried on have led to further economies, either in reduction of staff or in the adoption of labour-saving appliances. It is satisfactory to note that, notwithstanding the adverse circumstances under which coal-mining is carried on in this district, we are still able to show a higher average tonnage per person employed than any other district in the Midland coal-fields, with the exception of South Staffordshire, where the thick and easily worked coal-seams raise the average to an exceptionally high figure.

Foreign Competition.—Although the production of coal during the reign of Queen Victoria has grown from 30,000,000 to almost 200,000,000 tons, and we are still the largest coal-producing country in the world, it must not be overlooked that the increased output of the other coal-producing countries of the world has been even more marked than ours, and whereas 50 years ago the United Kingdom produced 70 per cent. of the whole output of the world, we are now only responsible for 33 per cent., whilst the output of the United States almost reaches our own quantity. In considering the question of foreign competition, it is interesting to note that whilst our average output per person employed (above and belowground) only reaches 300 tons per year, that of the bituminous coal-fields of the United States is 400 tons.

Commercial.—In my address last year, I alluded to the co-operation of colliery-owners for maintaining and increasing the selling price of coal, and regretted that an attempt to effect this purpose had failed. Since then I am glad to say that such an association has been formed in this district, and it has met with a fair amount of success, particularly in regard to the selling of gas-coal, and some advance has been obtained on this class of the production without disturbing our friendly relations with gas-producers. There is no doubt that we must seek further relief by this means of increasing the price of coal, to meet increased expenditure and prevent underselling. It would also assist this object, if a more uniform system of sizing the different classes of coal were adopted, so that each colliery selling the same class of coal would be on the same basis.

Problems of the Future.—The great progress made during the past few years in the Scotch coal-fields is largely due to the great care and attention given to the more careful cleaning, sorting, and sizing of the coal. The increasing tendency of consumers to use small and lower-class fuel should tend to increase the average sale-price of this part of the output, but a serious question is arising as to the surplus of large coal which the increased consumption of the smaller sizes leaves on the hands of the colliery-owners.

The greater depth to which coals are being worked will require further improvements in winding and hauling-appliances, not only with a view to quicker winding, but also for economy of steam-consumption. The tendency on all sides to reduce the hours of labour to a minimum will also render it necessary to meet the shorter hours by greater facilities for maintaining the output, and getting the workmen from the shaft to the face of the workings as quickly as possible. In fact, it is more necessary now than ever it was that we should be ready and willing to take advantage of all the facilities which modern science and engineering skill have placed at our disposal. Every subject of importance in the mining world must be carefully watched, and nowhere shall we have better opportunities for considering such matters than at our Institute meetings.

Mr. C. E. DE RANCE proposed a vote of thanks to the President, remarking that he was sure they would all feel with him that the Institute had shown wisdom in the choice of a President, whose addresses last year and on that occasion, directed as they were to practical questions which were before every colliery proprietor and manager, had shown him to be eminently fitted for the post of President of that practical society.

Col. J. STRICK seconded the motion, which was carried with acclamation.

DISCUSSION ON MR. JOHN D. BAILIE'S PAPER ON "THE STEAM-TURBINE ENGINE," ETC.*

Mr. JOHN D. BAILIE wrote that at the last meeting, the questions raised by members had reference chiefly to economy and durability, relatively to reciprocating engines. He would first suggest that the prevalent custom of expressing the steam-consumption of an engine in pounds per indicated horsepower was not a good one, nor did it of itself convey an accurate impression of the steam economy, to ascertain which, the mechanical efficiency also must be taken into account. It would be preferable when comparing the steam-consumptions of engines, to express them in pounds per brake horsepower, as the latter represented the energy available for external or useful work. Similarly, when comparing the steam-economies of combined plants, the engine and dynamo, engine and pump, engine and fan, or of whatever the combination may consist, should be considered as one complete plant, and the steam-consumption stated in pounds per electrical horsepower, per water horsepower, or per air horsepower, as the case may be. Unless this be done, mistakes were apt to occur.

It is of interest to remember, in the case of a combined plant, that the combined efficiency is something lower than that of either component: for example, the resultant efficiency of an engine and dynamo having individual efficiencies of 75 and 90 per cent. would be 67·5 per cent. And further, that the best resultant efficiency is obtained when the several efficiencies are equal, assuming of course that their sum remains the same. As an instance, the combined efficiency of an engine and dynamo having individual efficiencies of 80 and 94 per cent. would be 75·2 per cent., but if they each had an efficiency of 87 per cent. the resultant efficiency would be 75·69 per cent.

There is a tendency on the part of buyers to ascertain the steam-consumption of an engine per horsepower-hour at full load, and to ignore that at half-load, quarter-load, etc. This is a mistake, for at collieries, at any rate, the load fluctuates very much indeed, and the average is something considerably below the full load—the load-factor being frequently only about 0·5, or even less.

Further, a reciprocating engine with a very good steam-consumption when new and everything in first-rate order may have a very bad one after it has been at work for some time; and it may be accepted as

* *Trans. Fed. Inst.*, vol. xiii.

generally true that the more complicated the engine is the greater will be this increase in steam-consumption, for there are more parts to wear and get out of adjustment.

It is obvious that a triple or quadruple expansion-engine, with its many moving parts and rubbing surfaces, must require more oil than a simple engine; so that the attainment of high steam economy means an increased oil-consumption. Frequently this item does not receive sufficient attention. As an example of its importance, it may be pointed out that a saving in steam-consumption of 1 pound per indicated horsepower per hour with an engine indicating 100 horsepower would, in a working year of 50 weeks, each of 54 hours, amount to 270,000 pounds of steam; and assuming an evaporative duty of 10 pounds of water per pound of coal, this represents a saving of say 12 tons of coal, which, at 7s. 6d. a ton, would cost £4 10s. A saving of 1 pint of oil per day for a similar period (300 days) would amount to 37½ gallons, which, at 2s. 6d. a gallon, would cost £4 13s. 9d.; from which it is evident that in this case a saving of 1 pint of oil per day is more important than a saving of 1 pound of steam per horsepower-hour.

The term "economy" is a comprehensive one, and involves several considerations. It is dependent on, not only the steam-consumption per useful horsepower, but also on the interest on cost of plant and on the amount expended on land, buildings, and foundations; the cost of oil, of repairs and upkeep, and of attendance; and a fair comparison of two engines as regards economy can only be arrived at by taking these items into account.

Now, with regard to the economy of turbo plants, dealing first with the question of steam-consumption. The machines referred to below are not necessarily the most efficient that have been built; and they are selected solely because the writer had a more or less intimate personal knowledge of them.

A turbo-dynamo, with an output of 134 electric horsepower, now at work for a Lancashire corporation, gave, with a steam-pressure of 62 lbs. at the machine and a vacuum of 26¾ inches, a consumption of 20·1 lbs. of steam per electric horsepower at full-load and 22·3 lbs. at half-load —a rise of 11½ per cent. from full to half-load. A smaller plant of 67 electric horsepower supplied to the same corporation consumed 20·9 lbs. of steam per electric horsepower at full-load, the steam pressure at the machine being 90 lbs. and the vacuum 28⅛ inches.

A 266 electric horsepower turbo-dynamo driving an ironworks near Chester is interesting, as showing the adaptability of these plants,

and their economy under variable conditions of working and fluctuating loads. It is arranged to work either condensing or non-condensing, and to give its full output under either condition. The tests showed that the steam-consumption was, when running non-condensing, 32·22 lbs. per electric horsepower per hour at full-load and 44·18 lbs. at half-load; when non-condensing, but with 30° Fahr. of superheating, 30·97 lbs. per electric horsepower at full-load and 37·17 lbs. at half-load; and when condensing, but no superheating, with a vacuum of 25 inches, 19·51 lbs. per electric horsepower at full-load and 20·90 lbs. at half-load—a rise, from full to half-load, of only 7⅛ per cent. The boiler-pressure during the tests was 100 lbs. per square inch.

A 200 electric horsepower turbo-alternator with exciter, supplied to the Newcastle and District Electric Lighting Company, gave the following results, the steam-pressure at the machine being 70 lbs. per square inch, and the vacuum 26⅛ to 26¾ inches:—The consumption at full-load was 17·28 lbs. per electric horsepower per hour, at half-load 20 lbs., and at quarter-load 22·01 lbs., an increase, from full to quarter-load, of about 27 per cent.

A turbo-pump, comprising a 6 inches centrifugal pump coupled direct to a 200 horsepower steam-turbine, when running at 4,700 revolutions per minute, gave 73 water horsepower and a head of 172 feet. Though the steam-pressure was low (43 lbs. per square inch), the steam-consumption was only 32 lbs. per water horsepower.

The foregoing results show that the steam-turbine is an economical heat-engine, and can, at any rate, hold its own with the best engines of other types as regards efficiency.

In the smaller sizes, reciprocating engines may be taken as being somewhat lower in price than steam-turbines, but the latter have the advantage when engines of large power are required. It is evident that the interest on the amount spent on land, buildings, and foundations must be considerably less for steam-turbines than for reciprocating plant, for they are undoubtedly much more compact, an engine of 700 brake horsepower requiring only 41 square feet of floor-space; and there being no vibration or thrust, they stand on any firm level bed without being even bolted down.

The economy of the steam-turbine, with respect to the cost of oil, is obvious, as the only parts to be lubricated are the bearings, and they are of small diameter and rubbing surface. As stated in the paper, the same oil can be used over and over again, being passed through a filter when it becomes gritty.

The steam-turbine also has a distinct advantage as regards the cost of repairs and upkeep. The absence of reciprocating action, the perfect balance, the extreme simplicity, the scarcity of moving parts, and the effective lubrication, all tend to reduce the wear to a minimum; and when repairs are necessary, the lightness of the parts facilitates cheap and rapid handling. The Newcastle and District Electric Lighting Company's station is engined exclusively by steam-turbines; and as may be seen from their returns to the Board of Trade, the cost of repairs and renewals has been consistently lower than at any other electric supply-station, and it has never exceeded 2½ per cent. per annum on the initial outlay. Taken in relation to the current delivered to consumers, the costs of repairs and renewals during the last six years have been 0·10d., 0·27d., 0·14d., 0·16d., 0·12d., and 0·13d. per unit sold, or an average for the six years of 0·153d. per Board of Trade unit, or 1,000 watt-hours, or 1⅓ electric horse-power hours. It should be pointed out that these figures do not apply to the plant alone, but represent the cost of upkeep and repairs to the whole undertaking, including engines, dynamos, boilers, condensers, switch-boards, transformers, mains, buildings, and accessories of every description.

Two turbo-dynamos have been at work for about three years at a large manufactory at Walsall, and, with the exception of a fault in the stop-valve, have cost nothing in repairs since installed. Two turbo-dynamos have been in regular use for about five years in a cotton-mill at Heywood, and beyond the overhauling of the commutators, etc., have cost nothing whatever in repairs, and the engines are to all appearance as sound as when put down.

The low cost of attendance can best be shown by stating that at the Newcastle and District Electric Lighting Company's supply-works there are eleven turbo-plants, and two workmen can attend to them with ease —and to the main switch-board also.

In conclusion, it would appear that the steam-turbine has a higher all-round economy than the reciprocating engine, for the only two points on which the latter can compare with it are interest on outlay for plant and steam-consumption at full load; whilst as regards interest on the amount spent on land, buildings, and foundations, cost of repairs and upkeep, of oil, and of attendance, the steam-turbine is distinctly to be preferred.

The further discussion was adjourned.

Mr. W. Freakley read the following paper on "The Freakley Steam-carriage":—

THE FREAKLEY STEAM-CARRIAGE.

By W. FREAKLEY.

The "North Star" has been constructed to demonstrate the suitablity and superiority of steam for the propulsion of road-carriages and vehicles, and the designer's object has been the production of a motor-carriage, which shall be capable of withstanding the ever-varying and trying conditions appertaining to the rapid and economical carriage of passengers and merchandize over ordinary town and country roads; while at the same time, the simple construction of the machine enables it to be understood and manipulated by men of ordinary intelligence. The designer of the "North Star" has for many years watched with the keenest interest the results of the efforts of many inventors in the field of mechanical traction on common roads, and now that most of the obstructive restrictions (which were for so long a time a standing disgrace to the home of the steam-engine) are removed or modified, a wonderful amount of inventive ability has been brought to bear upon the problem of economical road-locomotion. No attempt can be here made to deal historically with this important subject, but a practical and dispassionate analysis (from an engineering point of view) of the innumerable attempts to solve the problem, point irresistbily to the conclusion, that for really useful every-day work, the steam-engine is likely to hold its own for a long time to come; and it is a noteworthy fact, that most of the leading engineers, whose opinions are entitled to the highest degree of respect, seem to be agreed upon this point.

The main frame of the Freakley steam carriage is composed of steel of the highest quality and great flexibility, the fore part being occupied by the engine and boiler, with provision for the driver and steersman, while the hind part is in the form of a brake or wagonette, with accommodation for 20 to 24 passengers.

The engine has vertical compound cylinders, which are carried upon steel frames, the steel piston-rods being attached to phosphor bronze cross-heads, from which hang short vibrating rods, which are connected to steel bell-cranks, to which in turn are attached the long tubular connecting-rods, the large ends of which are fitted with phosphor bronze

bearings, bored concave, so as to embrace the crank-pins, which are spherical in form and formed in one with the cranks, which are of the highest quality of phosphor bronze. The cranks are fixed at an angle of 90 degrees upon a mild steel shaft, which carries the valve-gear eccentrics and also a phosphor bronze driving-pinion, which works into a large spur-wheel upon the main axle of the road-wheels. The valves are actuated by the ordinary Stephenson link-motion, so that the carriage may be run in either direction with facility. The regulator, reversing-lever, brake, and steering mechanism are placed so as to give the driver full control of the machine, his position being such as to give him a clear view of the road. The steering-wheels are situated under the front end of the carriage. They are of narrow gauge, and mounted upon a swivel-axle, which carries the double elliptical springs by which the front of the carriage is supported. The arrangement is such as to give the utmost control over the movements of the machine, enabling it to be turned in its own length. The main road-driving wheels are mounted upon a compound differential axle, enabling the carriage to pass round the sharpest curves without undue tortion or straining. The main-axle journals are of the finest phosphor bronze and pivot-mounted, so as to preserve their true alignment and avoid undue friction. The main axle, crank shaft, and driving gear are carried upon an independent under-frame universally mounted, allowing of the free movement of the main carrying springs and carriage-body while preserving the perfect working-contact and distances of the driving mechanism.

The boiler is constructed on novel lines: it is of the water-tube type, the tubes being of copper, and solid drawn. The tube-plates are of Siemens-Martin steel of the finest quality. The firebox is made in sections, and arranged so as to be easily detached without disturbing the boiler, while the peculiar disposition of the parts gives a very rapid circulation of the water and a copious supply of dry steam, with a high degree of superheating. The water-level is controlled by means of an independent Worthington duplex pumping-engine, arranged so as to admit of the nicest adjustment. The water is passed through a heater, raising its temperature to over boiling-point. The safety-valves are of the most modern lock-up pop type. The construction of the boiler affords every facility for inspection, cleaning, or repairs, while the space occupied is abnormally small for the power given out. The casing enclosing the boiler is composed of asbestos-sheeting, enclosed within a sheet-iron outer case. The exhaust steam is passed through a superheater, which renders it generally invisible, except in very cold or damp

weather. The water is carried in suitable tanks, which act as supports for the seats of the carriage; while the coke fuel is carried in a suitable bunker on the front of the carriage.

The general arrangement is such as to afford the highest degree of flexibility and freedom from shocks and undue vibration. The working of the "North Star" steam-carriage during some hundreds of miles of experimental running, over the roughest and most hilly roads, has been very satisfactory, and the quantity of fuel used has been surprisingly small.

The general design admits of the most easy adaptation to the requirements of all kinds of road-traffic, seeing that any kind of carriage or waggon-body may be applied without the necessity of altering the main frame or motor.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE ROYAL SCOTTISH SOCIETY OF ARTS, 117, GEORGE STREET, EDINBURGH, SEPTEMBER 14TH, 1897.

SIR LINDSAY WOOD, BART., RETIRING-PRESIDENT, IN THE CHAIR.

The SECRETARY read the Annual Report of the Council as follows :—

THE EIGHTH ANNUAL REPORT OF THE COUNCIL.

The Council is pleased to congratulate the members of the societies affiliated to The Federated Institution of Mining Engineers upon the continued success that has attended the formation of the Institution.

The Institution was founded for the advancement of the sciences of geology, mining, and metallurgy, by the interchange of opinions, by the reading of communications from members and others, and by discussions; to supply information to the Government upon the practical requirements of legislation affecting mining and metallurgical industries; and more especially, to promote a more general recognition of the status of mining and metallurgical engineering as scientific professions.

The members receive the *Transactions*, comprising papers read at the meetings of the Federated Institutes and at the two General Meetings of The Federated Institution of Mining Engineers held in rotation in the various mining districts of Great Britain, and at one held in London in each year. A meeting of Students is held annually, when an approved essay is read upon a selected subject, and visits made to mines, etc.

These considerable advantages could not be obtained otherwise, without individual subscriptions being paid to each of the affiliated Institutes.

The present satisfactory position of the Institution would be increased if the members used their endeavours to extend its membership; and more especially if those who are also members of similar societies would exert their influence in favour of federation. By these means, the influence of the Institution, as representing mining engineers, would become more effective, and the value of the *Transactions* greatly enhanced.

The Institution now comprises six affiliated societies :—The Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil, and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The following table illustrates the progress of the Institution since its formation on July 1st, 1889 :—

Year.	No. of Members.	No. of Non-Federated.	Totals.
1889-90	1,189	50	1,239
1890-91	1,187	9	1,196
1891-92	1,415	19	1,434
1892-93	1,533	19	1,552
1893-94	2,068	123	2,191
1894-95	2,210	109	2,319
1895-96	2,301	81	2,382
1896-97	2,434	60	2,494

General Meetings of the members have been held in South Wales, in Lancashire, and in London, and the value of the communicated papers must be a source of satisfaction to the members. A Students' Meeting was held in South Yorkshire, in August, 1896, under the auspices of the Midland Institute of Mining, Civil, and Mechanical Engineers. The thanks of the Institution have been conveyed to the gentlemen who kindly allowed their collieries and works to be visited by the members during these meetings. The attendance of the members at the General Meetings has been satisfactory, although their residences are scattered over all parts of Great Britain and abroad.

The Council have awarded prizes to the writers of the following papers, which are printed in the *Transactions* (vols. x. and xi.), for the year 1895-6 :—

"The Causes of Death in Colliery Explosions." By Dr. John S. Haldane.

"Geological Description of the Gold-mines of the Transvaal." By Prof. L. de Launay.

"The Depth to Productive Coal-measures between the Warwickshire and Lancashire Coal-fields." By Mr. C. E. de Rance.

"Photography in the Technology of Explosives." By Mr. Alfred Siersch.

The Students' Prize has been awarded to Mr. Roslyn Holiday for his essay on "The Applications of Electricity to Mining Operations."

Presidential addresses have been delivered during the year to the members of The Federated Institution of Mining Engineers, by Sir Lindsay Wood, Bart.; the Chesterfield and Midland Counties Institution

of Engineers, by Mr. M. H. Mills; the Midland Institute of Mining, Civil, and Mechanical Engineers, by Mr. George Blake Walker; the Mining Institute of Scotland, by Mr. George A. Mitchell; the North Staffordshire Institute of Mining and Mechanical Engineers, by Mr. Joel Settle; and the South Staffordshire and East Worcestershire Institute of Mining Engineers, by Mr. R. S. Williamson.

The papers on geology comprise the following :—

"Possible Extensions of the Coal-fields of France." By Mr. J. Bergeron.
"Note on Extensions of the Coal-field of the North of France." By Mr. M. Bertrand.
"Notes on Borings at Netherseal, Ashby-de-la-Zouch, Leicestershire." By Mr. G. J. Binns.
"On the Occurrence of Certain Minerals at Netherseal Colliery, Leicestershire." By Messrs. G. J. Binns and George Harrow.
"Notes on the Venterskroom Gold-fields, South African Republic." By Mr. H. B. Bunkell.
"The Gold-fields of the Hauraki Peninsula, New Zealand." By the Rev. Joseph Campbell.
"Geology of Deepcar and its Surrounding Hills." By Mr. F. Coultas.
"The Eastern Extension of the Midland Coal-field, and the Exploration at Southcar." By Mr. George Dunston.
"Tin-mining in Tasmania." By Mr. H. W. Ferd. Kayser.
"Note on the Stratigraphy of the Newer Rocks of the Netherseal Borings." By Mr. C. Fox-Strangways.
"The Mineral Resources of the Colony of Queensland." By Mr. William Fryar.
"Transvaal Coal-fields." By Mr. Rowland Gascoyne.
"The Geology of Africa in Relation to its Mineral Wealth." By Mr. Walcot Gibson.
"Mining in Rhodesia." By Mr. Albert H. Halder.
"Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant." By Mr. W. T. Hallimond.
"Occurrence of Iron Ores and Iron Manufacture in the Weald." By Mr. C. E. Hawkins.
"The Coal Industry of the South-eastern States of North America." By Mr. Jeremiah Head.
"Notes on the Tellurium Mineral of Choukpazat, Burma." By Prof. H. Louis.
"Occurrence of Cinnabar in British Columbia, Canada." By Mr. William Hamilton Merritt.
"The Gypsum Deposits of Nottinghamshire and Derbyshire." By Mr. A. T. Metcalfe.
"The Deposit at the Mill Close Lead-mine, Darley Dale, Matlock." By Mr. Cyril E. Parsons.
"The Mineral Seams of New Monkland." By Mr. James Prentice.
"Cheshire Salt District." By Mr. C. E. de Rance.
"South Wales and Lancashire Coal-fields." By Mr. C. E. de Rance.
"The Kent Coal-field." By Mr. C. E. de Rance.

"Note on some Rock-specimens from the Borings at Netherseal." By Mr. W. W. Watts.

"The Lake Superior Iron Ore Region, U.S.A." By Mr. Horace V. Winchell.

Mining engineering and safety-appliances have been dealt with in the following papers:—

"Machine Coal-mining in Iowa, U.S.A." By Mr. H. Foster Bain.

"Notes on Auxiliary Haulage at Netherseal Colliery." By Mr. G. J. Binns.

"Notes upon Gold-mining in Burma." By Mr. A. H. Bromly.

"Cornish Methods of Mine Timbering." By Mr. G. P. Chaplin.

"Secondary Haulage." By Mr. W. Galloway.

"Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant." By Mr. W. T. Hallimond.

"Sinking, Surface-fittings, and Coal-cleaning Plant at Whistleberry Colliery, Hamilton." By Mr. James Hastie.

"Sinking Operations at Kingsbury Colliery, Warwickshire." By Mr. John P. Kenrick.

"Honigmann System of Boring and Sinking Shafts." By Mr. Th. Lichtenberger.

"Mining in Northern Argentina." By Captain C. C. Longridge.

"The Enlargement of a Shaft at Lidgett Colliery, without Interruption of Coal-winding." By Mr. Henry E. Maltby.

"Bumps and Outbursts of Coal." By Mr. F. G. Meachem.

"Use of Steel Girders and Props in Coal-mines." By Mr. E. F. Melly.

"Notes on Coal-mining." By Messrs. Algernon Noble and Norman Nisbet.

"Electric Haulage at Pleasley Colliery." By Mr. Jno. Piggford.

"Notes on the Sinking of Two Shafts at Claravale Colliery, near Wylam-upon-Tyne." By Mr. Frank R. Simpson.

"Safety-props for Supporting Cages in the Head-gear of Pits in Cases of Overwinding." By Mr. C. Sebastian Smith.

"Improved Apparatus for Drawing Timber in Mines." By Mr. Edward B. Wain.

"Pit-top Safety-fencing." By Mr. Simeon Watson.

"The Lake Superior Iron Ore Region, U.S.A." By Mr. Horace V. Winchell.

The following papers have been contributed on mechanical engineering:—

"The Steam Turbine Engine, and its Applications to the Mining Industry." By Mr. John D. Bailie.

"The Compound Winding-engine at the Great Western Colliery Company's Tymawr Pit: with Notes on its Comparative Steam Economy." By Mr. Hugh Bramwell.

"Eccentric Haulage-clip." By Mr. John Brown.

"Appliances for Winding Water." By Mr. W. Galloway.

"The principal Pumping-engine at Llanbradach Colliery." By Mr. W. Galloway.

"A Spring-coupling for Winding or Hauling-ropes." By Mr. H. W. Hollis.

"Lifting a Vertical Rising Main by Expansion." By Mr. William Howe.
"Economical Combustion of Coal for Steam-raising Purposes." By Mr. T. E. Parrington.
"Light Railways." By Mr. Leslie S. Robinson.
"On some Dangers attending the use of Steam-pipes." By Mr. A. L. Steavenson.
"The Duty of Cornish Pumping-engines, Past and Present, and as compared with others." By Mr. Nicholas Trestrail.
"Automatic Variable Expansion-gear applied to Balanced Slide-valve Winding-engines." By Mr. W. D. Wight.

The following papers have been contributed on the subjects of colliery explosions, coal-dust, safety-lamps, mine-ventilation, etc.:—

"Saving Life in Colliery Explosions." By Mr. Ernest J. Bailey.
"Shaw Gas-tester." By Dr. P. P. Bedson.
"The Detection and Estimation of Carbon Monoxide in the Air by the Flame-cap Test." By Prof. Frank Clowes.
"Determination of Fire-damp in French Collieries." By Mr. J. Coquillion.
"Suggested Rules for the Recovery of Coal-mines after Explosions." By Mr. W. E. Garforth.
"Improved Safety-lamp." By Mr. Jno. Gregory.
"The Phenomena of Colliery Explosions." By Mr. Donald M. D. Stuart.
"Adequate Ventilation and Noxious Gases: with Special Reference to the Recommendations of the English, French, Prussian and Austrian Fire-damp Commissions." By Mr. E. W. Thirkell.

The preparation of minerals has been described in the following papers:—

"Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant." By Mr. W. T. Hallimond.
"Sinking, Surface-fittings, and Coal-cleaning Plant at Whistleberry Colliery, Hamilton." By Mr. James Hastie.
"Screening-plant at Mossbeath Colliery." By Mr. Walter H. Mungall.
"Anthracite Coal-breaking and Sizing Plant at Glyncastle Colliery." By Mr. W. D. Wight.

Explosives and blasting have been the subject of the following papers:—

"Report on the Home Secretary's Explosives in Coal-mines Order, 1896." By the Council of the Mining Institute of Scotland.
"The Cost and Efficiency of Safety-explosives as Compared with Gunpowder." By Mr. H. Hall.
"Further Experiments with Explosives." By Mr. F. Winkhaus.
"The Danger of Employing Safety-fuzes for Blasting in Fiery Mines." By Mr. F. Winkhaus.

Electricity and its applications have been discussed in the following papers:—

"The Use of Electricity at Ackton Hall Colliery." By Messrs. H. St. John Durnford and Roslyn Holiday.

"The Applications of Electricity to Mining Operations." By Mr. Roslyn Holiday.

"Electric Haulage at Pleasley Colliery." By Mr. Jno. Piggford.

Metallurgy has been treated on in the following papers:—

"The Education of Metallurgists." By Mr. Saville Shaw.

"The MacArthur-Yates Process of Gold-extraction: Dry Crushing, with Direct Amalgamation and Cyanidation." By Mr. John Yates.

The miscellaneous papers have included:—

"Recovery of Cyanogen and other Residual Products from the Waste Gases of Coke-ovens." By Mr. Harold Bonser.

"Barometer, Thermometer, etc., Readings for the Year 1896." By Mr. M. Walton Brown.

"Description of Various Types of Ropeways, and Remarks as to their proper Selection." By Mr. W. Carrington.

"Railways and their Relation to the Coal Trade." By Mr. Clement Edwards.

"Notes upon Foreign Mining Laws and Adequate Areas for Mining Concessions." By Mr. H. D. Hoskold.

"An Underground Fire at Bridgewater Colliery." By Mr. A. Dury Mitton.

"An Improved Protractor." By Mr. R. F. Percy.

"The Determination of, and Use of, the Magnetic Meridian in Mine Surveying." By Mr. R. F. Percy.

"Notes on Water-supply." By Mr. C. E. de Rance.

"The Education of Mining Engineers." By Mr. George Blake Walker.

"Recent Progress in the Recovery of Bye-products from Coke-ovens." By Messrs. Geo. Blake Walker and L. T. O'Shea.

The preceding lists, including 91 papers, demonstrate the varied nature of the communications printed in the *Transactions* during the past year. Several of the papers have elicited most valuable discussions on subjects of especial interest, and the Council trust that the members will send in communications as liberally as heretofore.

The "Notes of Papers (107) on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications" have been continued, and should prove of value to the members.

The *Transactions* have been printed in two volumes (vols. xii. and xiii.), and the Council believe that they will be received with satisfaction by the members.

BOOKS, ETC., ADDED TO THE LIBRARY.

African Review, vols. ix-xi, and vol. xii., Nos. 243-258.

Annales des Mines de Belgique, vol. i., Nos. 3-4; vol. 2, Nos. 1-3.

Australian Mining Standard, vol. xii., Nos. 398-425; and vol. xiii., 426-463.

Bain, H. Foster, Coal-Mining by Machine Work in Iowa, octavo, 9 pages.

Barry Docks and Railways, Description of Undertaking, 1896.

British Association for the Advancement of Science, Report of the Sixty-Sixth Meeting held at Liverpool in September, 1896, octavo, 1025 pages.

—, Toronto Meeting, 1897, Preliminary Programme, with Maps and Illustrations, octavo, 69 pages.

British Society of Mining Students, vol. xviii., parts 5-6; vol. xix., parts 1-6; and vol. xx., parts 1-2.

Cardiff: Some Accounts of the Bute Docks Cardiff, and Surrounding Works and Industries, duodecimo, 49 pages.

Claudet, A. C., Notes on the Sampling of Argentiferous and Auriferous Lead, with Diagrams illustrating the Unequal Distribution (Segregation) of the Precious Metals, demy octavo, 4 pages.

Cory Brothers, British Coal Trade and Freight Circular, July 31st., 1896, to September 30th, 1897.

Denny, G. A., The Klerksdorp Gold-fields, being a description of the Geologic and of the Economic Conditions obtaining in the Klerksdorp District, South African Republic, crown quarto, 247 pages.

Engine, Boiler, and Employers' Liability Insurance Company, Limited, Chief Engineer's Report for 1895-96, crown quarto, 72 pages.

Engineering and Mining Journal, vol. lxii., Nos. 4-26; vol. lxiii., Nos. 1-26; and vol. lxiv., Nos. 1-17.

Federated Canadian Mining Institute, vol. i., 1896.

Franklin Institute, Journal, vol. cxlii., Nos. 2-6; vol. cxliii., Nos. 1-6; and vol. cxliv., Nos. 1-4.

Galloway, W., Coal-Mining, 1896, demy octavo, 39 pages.

Head, Jeremiah, American Rail- and Tram-ways, demy octavo, 64 pages.

—, On Charging Open-hearth Furnaces by Machinery, demy octavo, 26 pages.

Holmes, T. V., Notes on the Best Locality for Coal beneath the Permian Rocks of North-West Cumberland, demy octavo, 11 pages.

—, Notes on the Whitehaven Sandstone, demy octavo, 9 pages.

Institution of Mining and Metallurgy, Transactions, vols. 4 and 5.

London County Council, The Incorporation of Technical Institutions, prepared for the Technical Education Board of the London County Council, foolscap folio, 4 pages.

Manchester Geological Society, Transactions, vol. xxv., Nos. 1-11.

Mines, List of Mines in the United Kingdom of Great Britian and Ireland, and the Isle of Man, 1896, foolscap folio, 331 pages.

Mines and Quarries, Second Annual General Report upon the Mineral Industry of the United Kingdom of Great Britain and Ireland for the year 1895, by Dr. C. le Neve Foster, foolscap folio, 191 pages.

—, Mineral Statistics of the United Kingdom and the Isle of Man, 1896, foolscap folio, 151 pages.

—, Summaries of Statistics relating to the Mines and Quarries of the United Kingdom and the Isle of Man, 1896, foolscap folio, 30 pages.

New South Wales, Annual Report of the Department of Mines and Agriculture for the years 1895-96, foolscap folio, 154 pages.

New Zealand, Brunner Coal-mine Disaster, Report of the Royal Commission to inquire into, on March 20th, 1896, foolscap folio, 144 pages.

Northumberland and Durham Permanent Relief Fund, Actuarial Report by Mr. T. Y. Strachan, royal octavo, 22 pages.

O'Donahue, T. A., Colliery Surveying, demy octavo, 163 pages.

Ontario Bureau of Mines, Fifth Report for 1895.

Pennsylvania State College, Mining Bulletin, vol. ii., No. 6; and vol. iii., No. 1.

Phillips, J. A. and H. Louis, A Treatise on Ore-deposits, octavo, 943 pages.

Salis, Henry Rodolph de, A Chronology of Inland Navigation in Great Britain, crown octavo, 133 pages.

Sexton, A. H., Fuel and Refractory Materials, demy octavo, 263 pages.

South African Republic, Report of State Mining Engineer for the year 1896, foolscap folio, 62 pages.

South Wales Institute of Engineers, Transactions, vol. xx., Nos. 1-5.

Western Australia, Department of Mines, Gold-mining Statistics for 1896, and half-year ending June 30th, 1897.

—, Report of the Department of Mines for the year 1895, with Supplementary Notes on part of 1896, foolscap folio, 77 pages.

—, Report on the Forests of Western Australia, their Description, Utilisation, and proposed Future Management, with Plans and Illustrations, foolscap folio. 57 pages.

Willis, W. A., The Workmen's Compensation Act 1897, octavo, 76 pages.

Woodward, H. P., The So-called Lode Formations of Hannans and Telluride Deposits, demy octavo, 8 pages.

EXCHANGES.

Annales des Mines de Belgique.
British Association for the Advancement of Science.
British Society of Mining Students.
Federated Canadian Mining Institute.
Franklin Institute of the State of Pennsylvania, U.S.A.
General Mining Association of the Province of Quebec, Canada.
Institution of Mining and Metallurgy.
Manchester Geological Society.
Mining Society of Nova Scotia, Canada.
New South Wales, Department of Mines, Geological Survey.
Ontario Mining Institute.
*Revue Universelle des Mines, de la Métallurgie.
South Wales Institute of Engineers.

* No publications received during current year.

July 31st, 1897.

The Local Institutes in Account with The Federated Institution of Mining Engineers, for the Year Ending July 31st, 1897.

Dr.

	No. of Members.		Balance due at the beginning of the year.	Amounts falling Due during the Year.			
	Federated.	Non-Federated.		Calls made during the year.	Excerpts.	Transactions, Reducing Plates, etc.	Totals.
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	331	...	1 14 0	281 7 0	14 2 6	16 10 0	313 13 6
Midland Institute of Mining, Civil, and Mechanical Engineers	274	...	1 0 4	232 18 0	11 18 5	3 15 0	249 11 9
Mining Institute of Scotland	420	60	4 0 7	387 0 0	4 2 5	3 13 0	398 16 0
North of England Institute of Mining and Mechanical Engineers	1,109	...	29 1 4	942 13 0	45 0 1	43 17 9	1,060 12 2
North Staffordshire Institute of Mining and Mechanical Engineers	178	...	31 12 2	151 6 0	3 5 9	6 0 0	192 3 11
South Staffordshire and East Worcestershire Institute of Mining Engineers...	122	...	42 4 10	103 14 0	2 3 10	12 10 0	160 12 8
Totals	2,434	60	109 13 3	2,098 18 0	80 13 0	86 5 9	2,375 10 0

Cr.

	Amounts Paid during the Year.				Balance at July 31st, 1897.
	Balance from previous year.	Calls.	Excerpts.	Transactions, Reducing Plates, etc.	Totals.	
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	1 14 0	269 9 0	14 2 6	13 10 0	298 15 6	14 18 0
Midland Institute of Mining, Civil, and Mechanical Engineers	1 0 4	225 5 0	11 18 5	1 15 0	239 18 9	9 13 0
Mining Institute of Scotland	4 0 7	380 3 0	1 3 11	2 13 0	388 0 6	10 15 6
North of England Institute of Mining and Mechanical Engineers	29 1 4	940 19 0	45 0 1	2 10 0	1,017 10 5	43 1 9
North Staffordshire Institute of Mining and Mechanical Engineers	31 12 2	141 2 0	1 10 6	1 0 0	175 4 8	16 19 3
South Staffordshire and East Worcestershire Institute of Mining Engineers	42 4 10	56 2 0	0 12 9	...	98 19 7	61 13 1
Totals	109 13 3	2,013 0 0	74 8 2	21 8 0	2,218 9 5	157 0 7

Dr. THE TREASURER IN ACCOUNT WITH THE FOR THE YEAR

July 31, 1896—			£ s. d.	£ s. d.	
To Balance at Bank			683 0 3		
„ „ in Treasurer's hands			48 19 1		
				731 19 4	
To Subscriptions for year ending July 31, 1896—					
Federated—					
Chesterfield and Midland Counties Institution of Engineers			1 14 0		
Midland Institute of Mining, Civil, and Mechanical Engineers			0 17 0		
North of England Institute of Mining and Mechanical Engineers			28 18 0		
North Staffordshire Institute of Mining and Mechanical Engineers			23 13 0		
South Staffordshire and East Worcestershire Institute of Mining Engineers			37 8 0		
				92 10 0	
To Subscriptions for year ending July 31, 1897—					
Federated—					
Chesterfield and Midland Counties Institution of Engineers			269 9 0		
Midland Institute of Mining, Civil, and Mechanical Engineers			225 5 0		
Mining Institute of Scotland			356 3 0		
North of England Institute of Mining and Mechanical Engineers			940 19 0		
North Staffordshire Institute of Mining and Mechanical Engineers			141 2 0		
South Staffordshire and East Worcestershire Institute of Mining Engineers			56 2 0		
				1,989 0 0	
Non-Federated—					
Mining Institute of Scotland				24 0 0	
To Local Publications and Authors' Copies—					
	1895-96.		1896-97.		
Chesterfield and Midland Counties Institution of Engineers	.....		14 2 6		
Midland Institute of Mining, Civil, and Mechanical Engineers	.....		11 18 5		
Mining Institute of Scotland	1 10 3		1 3 11		
North of England Institute of Mining and Mechanical Engineers	.....		45 0 1		
North Staffordshire Institute of Mining and Mechanical Engineers	2 12 6		1 10 6		
South Staffordshire and East Worcestershire Institute of Mining Engineers	0 6 6		0 12 9		
The Federated Institution of Mining Engineers	0 9 2		44 1 4		
	4 18 5		118 9 6	123 7 11	
Carried forward				£2,960 17 3	

FEDERATED INSTITUTION OF MINING ENGINEERS. Cr.
ENDING JULY 31, 1897.

July 31, 1897.											
By Printing—			£	s.	d.	£	s.	d.	£	s.	d.
Transactions, Vol. X., printing			31	12	6						
						31	12	6			
„ „ XI., printing			421	17	1						
„ „ XI., plates			227	17	8						
						649	14	4			
„ „ XII., printing			493	0	3						
„ „ XII., plates			121	19	7						
						614	19	10			
									1,296	6	8
Excerpts, Vol. III.						1	8	6			
„ „ XI.						82	0	8			
„ „ XII.						69	13	10			
„ „ XIII.						2	13	0			
									155	16	0
Circulars						... ..			27	13	8
Proofs of Papers for General Meetings						.....			18	10	9
											1,498 7 1
By Addressing Transactions, etc. ...						.....			33	6	6
„ Postages—Circulars						14	15	9			
„ „ Correspondence ...						16	0	0			
„ „ Transactions						275	19	0			
									306	14	9
„ Stationery, etc.						.....			38	13	4
„ Insurance of Transactions						.....			2	0	0
„ Binding—Library						2	4	0			
„ „ Sundries						0	19	3			
„ „ Transactions						18	16	9			
									22	0	0
„ Reporting General Meetings						... ..			18	13	6
„ Expenses of General Meetings						.....			17	1	8
„ Incidental Expenses						... ..			3	3	0
„ Petty Cash						.....			5	14	4
„ Salaries, Wages, Auditing, etc.						.....			486	12	0
„ Indexing Transactions						.....			12	10	0
„ Travelling Expenses—Secretary						86	0	3			
„ „ „ Treasurer						16	1	6			
									102	1	9
											1,048 10 10
Carried forward											£2,546 17 11

Dr. THE TREASURER IN ACCOUNT WITH

	£ s. d.	£ s. d.	£ s. d.
Brought forward			2,960 17 3
To Sales of Transactions, etc.—			
	1895-96.	1896-97.	
Chesterfield and Midland Counties Institution of Engineers	.....	9 0 0	
Midland Institute of Mining, Civil, and Mechanical Engineers	0 3 4	1 5 0	
Mining Institute of Scotland	2 0 4	2 3 0	
North of England Institute of Mining and Mechanical Engineers	0 3 4	.....	
North Staffordshire Institute of Mining and Mechanical Engineers	1 16 8	.....	
South Staffordshire and East Worcestershire Institute of Mining Engineers	4 0 4	.....	
Members, etc.	.....	104 18 0	
	8 4 0	117 6 0	
			125 10 0
To Reducing Plates—			
	1895-96.	1896-97.	
Chesterfield and Midland Counties Institution of Engineers	.....	4 10 0	
Midland Institute of Mining, Civil, and Mechanical Engineers	.....	0 10 0	
Mining Institute of Scotland	0 10 0	0 10 0	
North of England Institute of Mining and Mechanical Engineers	.....	2 10 0	
North Staffordshire Institute of Mining and Mechanical Engineers	3 10 0	1 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	0 10 0	.....	
	4 10 0	9 0 0	
			13 10 0
To Advertizements			433 18 4
			£3,533 15 7

THE FEDERATED INSTITUTION OF MINING ENGINEERS.—*Continued.* Cr.

	£ s. d.	£ s. d.	£ s. d.
Brought forward			2,546 17 11
By Advertizements—Agreement Stamps	0 6 6		
„ „ Commission	125 6 5		
„ „ Printing	0 11 8		
		126 4 7	
„ Prizes, Students', Vol. XII.		5 0 0	
„ Translations of Papers		30 4 6	
„ Abstracts of Foreign Papers, Vols. XI. and XII.		88 5 2	
Barometer Readings, etc.		7 18 0	
„ Calendar		14 3 6	
„ Stock Room		19 6 1	
Library		0 12 3	
			291 14 1
			2,838 12 0
Balance at Bank		634 8 0	
„ in Treasurer's hands		60 15 7	
			695 3 7
			£3,533 15 7

THE FEDERATED INSTITUTION OF MINING

Liabilities.

	£ s. d.	£ s. d.
Sundry Creditors—		
Advertizements Paid in Advance	23 11 8	
Printing, etc.	900 0 0	
Postage of Transactions	80 0 0	
Abstracts of Foreign Papers	37 10 0	
Barometer Readings	8 0 0	
Prizes for Papers, Vols. X., XI., XII., and XIII. ...	40 0 0	
Index, Vol. XIII.	6 0 0	
		1,095 1 8
Balance of Assets over Liabilities		908 7 7

I have examined the above Balance Sheet, with the books and vouchers relating thereto, and certify that in my opinion it exhibits a correct view of the affairs of the Institution.

I have accepted the asset "Transactions in Stock" as valued by the Officials of the Institution.

JOHN G. BENSON,
Chartered Accountant.

Newcastle-upon-Tyne,
September 13th, 1897.

£2,003 9 3

ENGINEERS.—BALANCE SHEET, JULY 31, 1897.

Assets.

	£ s. d.	£ s. d.
Balance at Bank	634 8 0	
„ in Treasurer's hands	60 15 7	
		695 3 7
Subscriptions Unpaid, Year ending July 31, 1897—		
Chesterfield and Midland Counties Institution of Engineers	11 18 0	
Midland Institute of Mining, Civil and Mechanical Engineers	7 13 0	
Mining Institute of Scotland	6 17 0	
North of England Institute of Mining and Mechanical Engineers	1 14 0	
North Staffordshire Institute of Mining and Mechanical Engineers	10 4 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	47 12 0	
		85 18 0
Local Publications and Authors' Copies Unpaid—		
Mining Institute of Scotland	2 18 6	
North Staffordshire Institute of Mining and Mechanical Engineers	1 15 3	
South Staffordshire and East Worcestershire Institute of Mining Engineers	1 11 1	
The Federated Institution of Mining Engineers ...	1 12 11	
		7 17 9
Transactions Sold—		
Chesterfield and Midland Counties Institution of Engineers	3 0 0	
Midland Institute of Mining, Civil, and Mechanical Engineers	2 0 0	
North of England Institute of Mining and Mechanical Engineers	41 7 9	
North Staffordshire Institute of Mining and Mechanical Engineers	4 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	11 0 0	
		61 7 9
Reducing Plates—		
Mining Institute of Scotland	1 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	1 10 0	
		3 10 0
Advertizements unpaid		392 18 4
		1,246 15 5
Transactions in Stock		756 13 10
		£2,003 9 3

The CHAIRMAN (Sir Lindsay Wood) remarked that the report of the Council was satisfactory. Since the formation of the Institution in 1889, the membership had increased from 1,239 to 2,494, which showed that the members of the various associations appreciated the value of federation. Mining was a very important branch of the industry of this country, and he looked to the members to increase the efficiency both of the mechanical and engineering side of the profession as well as to promote those matters which pertained to the preservation of the lives of the workmen in the mines. They were not wrong in congratulating themselves if they were making progress in that way.

ELECTION OF OFFICERS.

The SECRETARY announced the following elections of officers by the Council:—

PRESIDENT.

Mr. A. M. CHAMBERS.

VICE-PRESIDENTS.

Mr. J. B. ATKINSON.	Mr. J. T. FORGIE.	Mr. M. H. MILLS.
Mr. W. N. ATKINSON.	Mr. G. B. FORSTER.	Mr. J. NEVIN.
Mr. E. BAINBRIDGE,	Mr. W. E. GARFORTH.	Mr. A. SOPWITH.
Sir LOWTHIAN BELL, Bart.	Mr. W. J. HAYWARD.	Mr. GEO. A. MITCHELL.
Mr. W. COCHRANE.	Mr. GEORGE LEWIS.	Mr. E. B. WAIN.
Mr. J. S. DIXON.	Mr. JAMES MCMURTRIE.	Sir LINDSAY WOOD, Bart.
Mr. T. DOUGLAS.	Mr. GEORGE MAY.	

TREASURER.

Mr. REGINALD GUTHRIE.

AUDITOR.

Mr. JOHN G. BENSON.

STUDENTS ESSAY.

The SECRETARY reported that the Council had presented to Mr. Andrew Burt, the prize (offered to students) for his paper on "The Methods of Working Minerals, Secondary Haulage and Ventilation in Fifeshire."

Mr. H. M. Cadell's paper on "Submarine Coal-mining at Bridgeness, N.B.," was read as follows:—

SUBMARINE COAL-MINING AT BRIDGENESS, N.B.

By HENRY M. CADELL.

The coal-field of Borrowstounness, or Bo'ness as it is now generally called, occupies an isolated position on the southern shore of the Firth of Forth in Linlithgowshire. It is small in area, the existing collieries on the Kinneil and Grange estates being included within a space of about 3 square miles, but notwithstanding this it can boast of having been a producer of coal within a period extending over no less than seven centuries. There are records of coal-mining on the lands of Carriden about a mile east of Bo'ness, in the end of the eleventh century, but the coal-mining of those days was confined to nibbling timidly at the outcrops of the seams, and it was not till the eighteenth century (when steam-power came to the assistance of the miner) that the resources of the coal-field could be practically developed.

The oldest plans and documents in the writer's possession date from the year 1770, when the writer's family acquired the collieries on Grange estate and began to actively develop them. At that time, this part of the coal-field had been extensively opened up by the "old people," and had many ancient pits and workings whose history had been lost in the mists of antiquity. The minerals on Grange have been mined by four successive generations of the writer's family continuously for the last 126 years, and as no mine however valuable can live for ever, the part of the coal-field under the land has at last become very nearly exhausted. It was ascertained a century ago that the best seams extend northwards under the sea, and cropped up on the opposite coast of Fife 3 miles away, where they were worked rather extensively at the beginning of this century. When therefore the coal-seams under the land became exhausted, it was necessary to resume the submarine workings and extend them seawards with the aid of modern machinery.

It is not at present the writer's intention to give a general description of the Bo'ness coal-field, which, however, has many points of geological and historical interest about it. This might, perhaps, form the subject of some future communication. But it may now be stated that this coal-

field occupies the same geological position as the edge coal-seams of Midlothian, or the coal-seams of Balbardie, near Bathgate, in the southern part of Linlithgowshire. These measures occupy the middle zone of the Scottish Carboniferous Limestone Series, between the bands of marine limestone that characterize the Upper and Lower divisions of this part of the Carboniferous system. The lowest of the Upper Series of marine bands is known as the Index Limestone from the indication which its presence gives of the existence of workable coal-seams beneath. The following general section of the Bo'ness coal-field, taken from the Index Limestone downwards, shows that the productive coal-bearing strata have, so far as is at present known, a thickness, roughly speaking, of 900 feet.

	Thickness of Strata. Feet.
Upper Coal-seams—	
Strata, sedimentary and volcanic, below Index Limestone...	133
Splint Coal-seam	3
Strata	47
Corbiehall Coal-seam	3
Strata	60
Upper Ironstone and *Seven Feet Coal-seam*	10
Strata	50
Thick beds of trap, interbedded	120
Wester Main Coal-seam or shales	30
Strata, volcanic rocks (trap), an irregular seam, the *Wandering Coal-seam*, and a bed of sandstone below	213
Lower Coal-seams—	
Red Coal-seam	3
Strata	97
Lower Ironstone, strata, and *Six Feet Coal-seam*	20
Strata	38
Easter Main Coal-seam	3 to 4
Strata	100
Smithy Coal-seam	2½ to 3
Strata	15
Carsey Coal-seam	1 to 1½
Total	950

The general inclination of the rocks is towards the west, although there are many local deviations in the dip of the strata. The upper coal-seams occur only in the western part of the coal-field, where they have been worked in the Kinneil colliery, both under the land, and, to a small extent, under the foreshore. The seams worked in the Grange and Bridgeness collieries in the eastern part of the field belong exclusively to the Lower Series from the Red coal-seam downwards.

The coal-field is traversed by several faults, the most important of which run usually in an east-and-west direction parallel to the shore. As their downthrow is towards the north, their effect is to depress the strata by a series of large steps, and drop the seams, some of which crop out on the land, deep down below sea-level, as is shown on the accompanying cross section at Bridgeness (Fig. 1, Plate VII.). A reference to the section and the accompanying plans (Fig. 2, Plate VIII., and Fig. 3, Plate VII.) shows that the present submarine workings are bounded on the south by one of these faults which runs along the coast in an east-and-west direction and crops out beneath the superficial deposits of the foreshore along a line located about about half way between the original high and low-water mark.

The configuration of this part of the coast, it may be mentioned, has of late years been greatly altered by the reclamations that are being steadily carried out by the writer, and a fresh portion of the flat, muddy foreshore is being embanked at Bridgeness, and raised above sea-level every year. The high-water line is thus being constantly pushed farther out to sea, more than 10 acres of land having been rescued from the sea to the east of the harbour since the submarine workings were opened. The land thus reclaimed is shown on the accompanying plans (Figs. 2 and 3).

The general question of submarine coal-mining is one of much interest, as there are many parts of the sea-bed beneath which valuable mineral deposits are known to exist, and could we calculate on being able to reach and work them safely and cheaply, a considerable addition would be made to the available mineral resources of the country. In order to carry on such work, the geological conditions of the district must be suitable, and at Bridgeness these conditions are all or nearly all that could be desired. The bed of the Firth of Forth, although very deep at places, is covered first by a stratum of very hard, stiff, unstratified glacial "till" or Boulder Clay, full of ice-worn stones and boulders. This deposit covers the solid rock, below nearly every part of the sea-bed that has been pierced by shafts or bore-holes in this locality. On the top of the till, there is a deposit of rich brown or reddish plastic clay, 30 or 40 feet thick, finely laminated at places, and generally free of sand and stones except at the upper and lower edges. It occurs on both shores of the Firth, and extends for several miles along the coast, being used at places where it overspreads the shore and rises above sea-level, for brick and tile-making purposes. This stratum is of great importance to the miner, as it covers up the rock like a tight waterproof sheet and prevents the

sea from reaching the underlying strata. Being plastic, it can bend down when the rock subsides during the process of working the coal-seams below, on the longwall system. The brown clay is covered by beds of sandy mud and silt of recent alluvial origin, full of water at places and liable to run like quicksand when disturbed.

At places, these superficial deposits reach a great depth, and there is no doubt that in pre-Glacial times, when the land stood several hundred feet higher than now, the ancient river Forth ran along a deep valley, whose bottom was probably at least 400 feet below its present bed in this district. There is at other parts of the estuary clear evidence of an ancient buried river-channel, and at Bridgeness the rock-surface which crops up on the shore, as shown in the accompanying section (Fig. 1, Plate VII.), shelves down comparatively steeply towards the centre of the estuary from the promontory of hard whinstone on which Bridgeness Tower stands. At the point of Bridgeness Pier, situated near low-water mark, the rock-surface drops to about 100 feet below the level of high tides, the intervening space being principally occupied by the deposits that have just been described.

The coal-seams in the immediate vicinity had been worked for many years from No. 5 pit, sunk on the shore about 90 years ago. The workings from this shaft had been gradually extended beneath the foreshore to a little beyond low-water mark, but seeing that the seams were found to be thrown down by faults and to dip towards the north, the development of the coal-field in that direction from the old shaft became yearly more difficult and costly. The writer's father, the late Mr. Henry Cadell, of Grange, who, like his predecessors, both owned and mined his own minerals, seeing that a new shaft farther seaward was absolutely necessary, resolved to sink as far out as possible to catch the seams at a greater depth. Owing to the distance down to the rock and to the fact that the sea surrounded the spot chosen, this work was not successfully accomplished without considerable difficulty and expense.

Sinking of No. 6 Pit.—The new pit (No. 6), which is situated a few feet above low-water mark, 450 feet east of the tidal harbour of Bridgeness, commands a large and valuable area of submarine coal. The rise and fall is here from 12 to 19 feet at high spring tides; and the harbour, at which most of the coal is shipped, is large enough to accommodate vessels of 600 tons burden. The first attempt at sinking was made in 1862, when an embankment about 750 feet long was run out towards low-water mark, parallel to and about 240 feet east of the old pier, the

shaft being located at the point of this bank. The difficulties and expense experienced in carrying down the shaft through the soft mud and running sand were, however, such that it was deemed expedient to suspend operations.

Another attempt was made in a more determined and energetic manner in 1869-70, when a staging of trestle-work was built out from the embankment to the site of and surrounding the proposed shaft, which was to be sunk by means of a cast-iron shoe composed of segments bolted together carrying the heavy brick casing of the shaft. As the excavation within the area so enclosed proceeded, additional walling was to be added at the top, the gradually increasing weight of which, in proportion to the progress of the excavation, was thought to be sufficient to cause the whole to subside. But after having gone down some distance, it was found that the unequal pressure on the sides so distorted the shaft from the circular form that it eventually altogether collapsed. Besides, the superincumbent weight was not nearly sufficient to cause the cutting edge to keep ahead of the excavation. The consequence was that, with the rising tide, the mud frequently burst up below and filled the pit, leaving a large subsidence on the outside when the tide retired. Before the pit was half way down to the rock, it was evident that this system was destined to failure, and the works were again abandoned for a time.

A third and successful attempt was made in 1878, after a lapse of eight years, at a point a short distance north of the last sinking, when cast-iron cylinders, 13 feet in external diameter, were employed. Each cylinder was 1¼ inches thick, 6 feet deep, and weighed about 6 or 7 tons. The machinery was borrowed from Messrs. William Arrol & Company, who had just used the same apparatus for the sinking of the piers of the Caledonian railway-bridge over the Clyde at Glasgow. This time, instead of emptying the shaft, it was at first allowed to remain full of water so as to equalize the pressure on both sides, and the soft materials were taken out by means of the Milroy digger, an apparatus working on nearly the same principle as the Priestman dredge. When open, the digger resembled an inverted crown, the blades hanging down ; on reaching the shaft-bottom the blades sank into the mud and closed, whereupon the apparatus, having now assumed a form resembling an open umbrella, was drawn up by a separate set of chains attached to the blades, and not to the frame. By this means the sinking was successfully carried out for the first part of the distance. The open digger was lowered in the shaft through the water to within 6 feet of the bottom, and was then allowed to drop and fill. Each time it brought up 1 or 2 tons of stuff. On

reaching the surface, the pulley overhead was drawn aside, and the digger moved away, so as to drop its load into a tram, as shown in Figs. 4, 5, and 6 (Plate VII.). The cylinders were brought by sea from Glasgow in barges, which were towed close alongside of the pit, as illustrated in Figs. 4, 5, and 6. As the digging proceeded, and the tubes sank, new cylinders were lifted from the boat by the travelling gear used for the digger and placed in their position in a very easy and expeditious manner. To help the tube to sink, it was loaded inside with cast-iron weights, in the form of a ring of segments that rested on the flanges, and were built in and tightly wedged and keyed together with wooden keys, each segment weighing about 14 cwts., and being just the size required to fit neatly inside the cylinders. Each cylinder, when fully loaded, contained 6 tiers of 6 segments, or 36 segments in all, built in, like bricks in a well. These weights not only added to the dead load of the cylinders, but helped to stiffen the tubbing against external pressure and prevent the pit from collapsing like its predecessor. When fully loaded, the weight of each cylinder was thus equal to about 31 tons. A section of the ground passed through is shown diagrammatically in Fig. 7 (Plate VIII.), and the details are given on page 244.

On August 1st, 1878, the first cylinder was placed in position and digging began. Although the tube was well loaded, sinking was slow for a time, and did not average 1 foot per day. After the surface-mud, which was here stiff, had been pierced, progress was more rapid, and on August 20th, 1878, the cylinders sank 4 feet 9 inches; on August 21st, 4 feet 7 inches; and on August 22nd, after the eighth cylinder had been put on, the whole immediately moved down 9 feet 2¼ inches. This was the most rapid speed that was ever attained in one day; and after this, when the strong brown clay was reached, progress became very slow. One difficulty that arose was caused by the want of weights to overcome the necessary friction, which proved to be much greater than had been calculated on at first, and it was impossible to get the full complement supplied in time by the makers and put into each cylinder. As a consequence, a great deal of digging went for nothing. It was ultimately found necessary to empty the pit of water, as the digger did not work nearly so well in the stiff clay as in the soft mud and sand. The digger formed a round sump in the centre (Fig. 8, Plate VII.), and left a bank of clay all round, which had to be cleared away by men every now and then.

When the tide rose outside, a great bulging up of the clay frequently took place (Fig. 9, Plate VII.); the removal of this caused much extra

work, which might have been avoided had there been enough weights available to keep the cutting edge always well ahead of the excavation. This bursting-up of the bottom also caused a subsidence around the pit on the surface, which had to be filled up.

Another difficulty that had to be contended with was to maintain the perpendicularity of the sinking, as the cylinders frequently sank faster on one side than on the other, causing the tube to list over towards the softer side, crush the strong guide-piles aside and throw the shaft considerably from the vertical. This difficulty was overcome by building up the weights in each cylinder on the elevated side (Fig. 10, Plate VII.), and by emptying a heap of mud discharged from the digger against the depressed side. At one time, the axis of the shaft was displaced from the verticality to the extent of about 20 inches, but by these means it was brought back to the exact perpendicular line before the sinking terminated.

On October 8th, 1878, as the digger was being wound up with a heavy load of clay, the chain broke, and it fell from a height of 50 feet back into the pit and cracked the lower cylinder carrying the cutting edge. After this accident, the excavation was carried on by hand to the rock, a distance of 25 feet. On November 15th, the cutting edge was 89½ feet below the top of the scaffolding, and the clay excavated clean away from under the lowest cylinder; and although the total superincumbent weight was about 400 tons, the cylinders could not be made to sink further owing to skin-friction, that caused the heavy tube to remain securely suspended. From this point to the rock, the distance was only about 13 feet, and the intervening strata of sand and till or boulder clay, being hard and strong, it was determined to sink the remainder of the distance by the aid of ordinary cribs of wood, the cast-iron weights in the cylinders being in the meantime removed. The rock-bed was reached in this manner, and a strong brick wall was brought up from the rock to support the cylinders in case of any future movement, and the whole shaft was completely lined with brickwork from top to bottom. When finally completed, at the end of 1878, the shaft was as tight as a bottle and perfectly plumb.

The sinking to the rock occupied 5 months, but had there been available a sufficient quantity of weights to prevent the ever-recurring in-bursting of the bottom, it could have been accomplished within a much shorter time, and at considerably less expense.

The total cost of sinking to the rock was as follows:—

	£	s.	d.
Staging, timber	219	13	0
,, bolts	2	12	11
15 cast-iron cylinders, 13 feet in diameter and 1¼ inches thick	943	14	11
Freight of same	178	18	5
Use of digger and machinery	104	14	11
Return carriage of same to Glasgow	9	9	9
Belts for machinery	2	13	5
Weights, less value of metal returned	57	9	6
Bricks for cradling	30	0	5
Labour, embanking and scaffolding	72	4	4
Levelling rock for foundation of cylinders ...	21	7	3
Sinking cylinders	175	5	7
Cradling shaft	73	11	7
Total cost	£1,891	16	0

The remainder of the shaft was sunk in the ordinary way to the Main coal-seam. The whole time occupied, from August 1st, 1878, when the first cylinder was placed in position, to February 20th, 1880, when the Main coal-seam was struck at a depth of 340 feet, was a little over 18 months.

The following is the whole section passed through :—

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	From top of mud to top of cylinders and mouth of shaft (now banked up)	18	3	18	3
2	Gravel, ballast, etc.	2	0	20	3
3	Bluish-green mud, with sand and stones	10	0	30	3
4	Sand, with mud and stones	28	4	58	7
5	Sand, clean, dry, and yellow	0	6	59	1
6	Brown clay, fine and clean	33	0*	92	1
7	Gray sand and stones	5	6	97	7
8	Stiff till or boulder clay with glaciated stones ..	5	8	103	3
9	Sandstone, blaes, and fakes ...	9	10	113	1
10	Blaes (non-bituminous shale) ...	5	11	119	0
11	Ironstone-band ...	0	3	119	3
12	Blaes	1	1	120	4
13	Ironstone-band ...	0	1	120	5
14	Dark grey sandstone	3	8	124	1
15	Sandstone, white ...	2	10	126	11
16	Blaes	17	7	144	6
17	Ironstone-band ...	0	3	144	9
18	White calmy blaes	0	8	145	5
19	Dark hard blaes ...	0	6	145	11
20	White clay-bed, calmstone ...	0	9	146	8
21	Whinstone (dolerite)	8	0	154	8
22	White sandstone ...	38	3	192	11
23	Dark sandstone ...	2	7	195	6
24	Faikes	2	5	197	11
25	Blaes	0	7	198	6
	Red Coal-seam —				
26	**COAL**	3	0	201	6
27	Light fire-clay and dark sandy blaes	2	0	203	6
28	White sandstone ...	11	10	215	4
29	Blaes	6	2	221	6
30	Ironstone-band ...	0	4	221	10
31	**CANNEL COAL**, coarse	0	5	222	3
32	Sandy blaes ...	8	4	230	7
33	Ironstone-band ...	0	2	230	9
	Fire-clay Coal-seam —				
34	**COAL**	1	2	231	11
35	Fire-clay (underclay)	5	4	237	3
36	**COAL**	0	2	237	5
37	Soft dark sandstone	3	0	240	5
38	Faikey blaes ...	12	0	252	5
39	Dark hard sandstone	6	1	258	6
40	Blaes	2	2	260	8
41	Ironstone	1	5	262	1
42	Blaes and sandstone	1	6	263	7
43	Black shale (oil-shale)	3	0	266	7

* Length of cast-iron cylinders was 90 feet 3 inches, and of the brick building 13 feet below.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
44	Ironstone-band ...	0	2	266	9
45	Sandstone	6	4	273	1
46	Faikes	1	0	274	1
47	Blaes and faikes ...	5	6	279	7
48	Faikes and sandstone	5	6	285	1
49	Soft faikes	2	0	287	1
50	Blaes	7	3	294	4
51	Ironstone-band (kennel)	1	3	295	7
	Lower Ironstone and Parrot Coal-seam—				
	Ft. Ins.				
52	**COAL** (Craw coal-seam) 0 9				
53	Clay with ironstone nodules ... 0 3				
54	**COAL** (Parrot or Cannel) ... 0 8				
55	Blackband ironstone... 0 3				
56	Light fire-clay (Maggie) ... 0 2				
57	Ironstone-band ... 0 4				
58	Light soft shale (holing) ... 0 3				
	——	2	8	298	3
59	Sandy blaes ...	5	2	303	5
60	**COAL**	0	5	303	10
61	Sandy blaes ...	1	4	305	2
62	Coarse sandstone ...	3	6	308	8
	Six Feet Coal-seam—				
	Ft. Ins.				
63	**COAL** ... 2 9				
64	Dark sandstone band 1 3				
65	**COAL** ... 1 5				
66	Daugh ... 0 4				
67	**COAL** ... 0 4				
	——	6	1	314	9
68	Dark shaley sandstone ...	2	8	317	5
69	Hard faikes... ...	8	5	325	10
70	Blaes	2	11	328	9
71	Ironstone	0	3	329	0
72	**COAL** (cannel and common)... ...	1	2	330	2
73	Dark sandstone ...	3	3	333	5
74	**COAL** (cannel and common)... ...	1	2	334	7
75	Dark sandstone ...	3	2	337	9
	Easter Main Coal-seam—				
76	**COAL**	3	0	340	9
77	Dark freestone ...	3	8	344	5
78	Fakes and sandstone	8	7	353	0

The workable coal-seams opened out in No. 6 pit are four in number.

(1) *Red Coal-seam.*—This seam, averaging 3 feet in thickness, with a very strong freestone roof, had been previously worked from No. 5 pit under the foreshore, and the new shaft went down on the waste of the Red coal-seam pillar-workings. This seam, although of fair quality, has not been worked for some years, principally because it was situated too near the surface of the rock, and might crop out against the bed of the river with danger to the colliery. In point of fact this actually occurred in 1881, when the Red coal-seam workings were cut off by a wall of boulder clay at a depth of 217 feet, 1,290 feet north-west of Bridgeness pier, but without any dangerous results. This and subsequent experience has shown that there is in such an event not much danger to be apprehended with the good clay-and-till covering that the rock here possesses, and a new section of the seam is at present being opened out.

About 30 feet below the Red coal-seam, there is a seam a little over 1 foot in thickness, known as the Fire-clay coal-seam, from the bed of fire-clay of about 5½ feet thick on which it rests. This seam was mined for the fire-clay in other parts of Grange estate, when brick-making was carried on, but since the brickworks have been closed the seam has remained untouched.

About 30 feet farther down, a seam of oil-shale 3 feet in thickness was passed through. Although strong, and apparently of fair quality, its commercial value has never been tested.

(2) *Ironstone and Parrot Coal-seam.*—The next important seam in descending order is the Ironstone and Parrot coal-seam, which is now being regularly worked under the sea. This seam consists of three parts, which are as follow : —

	Ft.	Ins.
Roof—Blaes		—
Kennel ironstone	1	3
Seam—Craw coal	1	0
Blaes	0	4
Parrot coal	1	0
Ironstone	0	2½
Blaes and balls	1	1
Brushing—Faikes	1	10
Floor—Faikes		—

The principal and by far the most valuable portion is the cannel or parrot coal, which varies in thickness from 12 to 17 inches in different parts of the colliery. The following description and analysis of the coal made some years ago by Mr. Geo. R. Hislop is still applicable, except that in some cases the seam has recently been found, when tested practically, to give considerably better results than those obtained by Mr. Hislop.

Mineralogical Characters.—The coal is black, with considerable lustre and brown streak; fracture undulating and partly inclining to saclariform, and containing numerous impressions of *Stigmaria;* cross-fracture, small conchoidal to angular, with some slight deposits of calcium carbonate; very compact, but moderately cohesive; on the fire it intumesces and agglomerates; colour of ash, light brown; thickness of seam, 17 inches; mean specific gravity, 1,280 (water, 1,000); and weight of 1 cubic foot, 80 pounds.

The chemical analysis is as follows:—

	Per Cent.	Per Cent.
Volatile matter (containing 0·50 of sulphur) ...		33·25
Coke—		
Carbon	59·67	
Sulphur	0·34	
Ash	5·54	
		65·55
Water expelled at 212° Fahr.		1·20
		100·00

The results in gas-making are as follows : —

Gaseous products:—		
Gas, per ton of coal at 60° Fahr., and barometer at 30 inches	11,120	cubic feet.
Gas from 1 cubic foot of the coal	397·14	,,
Specific gravity of the gas	592	(air 1,000).

Hydro-carbons absorbed by bromine ...	11·00 per cent.
Durability of 1 cubic foot by 5 inches jet flame	59 mins., 48 secs.
Value of 1 cubic foot of gas in sperm ...	723·60 grains.
Value of gas from 1 ton of coal in sperm ...	1,149·49 pounds.
Illuminating power of gas in standard candles	30·15 candles.
Sulphuretted hydrogen (H_2S) in foul gas ...	1·50 per cent.
Carbonic acid (CO_2) in foul gas	1·75 ,,
Carbonic oxide (CO) in foul gas	5·25 ,,
Sulphur eliminated with volatile products	11·20 pounds.
Liquid products:—	
Tar, per 1 ton of coal	14·60 gallons.
Ammoniacal liquor, per 1 ton of coal ...	5·25 ,,
Strength of ammoniacal liquor	4·50 degrees Twaddle.
Hygrometric water, per ton of coal ...	2·68 gallons.
Aqueous absorbent capacity of coal (determined by complete saturation)	1·30 per cent.
Solid products:—	
Coke, per ton of coal...	1,468·32 pounds.
Carbon in the coke	91·55 per cent.
Ash in the coke	8·45 ,,
Sulphur in coke per ton of coal	7·61 pounds.
Heating power of 1 pound of coke (water from boiling-point into steam)	12·57 ,,

The Craw coal, which is here about 1 foot in thickness, forms the upper part of the seam, and is used chiefly for house coal and steam raising purposes. The ironstone, a thin irregular bed of black band lying immediately below the parrot, disappears at places altogether, and is never over 4 inches thick. It is scarcely remunerative, and is at present merely worked as a bye-product. The seam is brushed on the pavement, a thin band of kennel ironstone, which occurs immediately above the Craw coal, being left on to form the roof of the working. In other parts of the coal-field, the ironstone is thick and good, and forms the most valuable part of the seam. At these places, the cannel is generally thinner and of less value. The Parrot seam is worked on the longwall system in successive fetches, and being near the Main coal-seam is reached by cross-cut mines from the Main coal-seam dook. The part of the seam to the rise, on the western side of the pit, is practically exhausted, and the whole of the present workings are to the dip, and are located to the north-west of the shaft, reaching at their outer extremity to 1,500 feet below low-water mark. The accompanying plan (Fig. 2, Plate VIII.) shows the style of working, about which there is little which calls for much further description.

In previous workings from the shore, at Grangepans, nearly ½ mile

west of No. 6 pit, the seam was many years ago ascertained to crop out on the upthrow side of the 70-feet fault at a depth of 137 feet below sea-level. The working was actually carried on for about 150 feet with a boulder-clay roof, which was so hard and strong that its true character was not at first noticed. At one place, an ice-worn boulder of hard brown sandstone about 3 feet in length, ellipsoidal in shape, and splendidly striated from end to end, rolled out of a hollow in the rock-surface in which it had lain snugly buried since the glacial period, when the Forth valley was occupied by a huge glacier. This was the first experience of striking the bed of the Forth at any depth. The outcrop of the Red coal-seam workings in 1881 at a depth of 217 feet has been already mentioned. Since then, the Ironstone and Parrot coal-seam has apparently again been worked to the crop, this time, at a depth of about 400 feet, in the western part of the present workings. As shown on the plan (Fig. 2, Plate VIII.), the level, *AB*, as it proceeds westward, swings round to the north, showing that the strata here lie in a basin and rise upwards to the west. At this point, the faces have been cut off in succession by the seam becoming broken up and mixed with clay which forms, no doubt, the beginning of the outcrop. The seam has not been actually worked out to the boulder clay, but from all appearances that bed cannot be far off. Happily, the geological nature of the ground above has prevented any further inconvenience than the important one of cutting off a section of the workings at a place where the quality of the seam is particularly good.

(3) *Six Feet Coal-seam.*—This seam, the third in descending order, is at present being opened up to the dip. The coal is of good quality, but the seam contains one thick band of stone and some smaller ribs that require picking and cleaning on the pit-hill to make it easily marketable. The seam has been extensively worked to the rise, and the band of stone in it supplies material for stowing and building where the longwall system is adopted. At one place, the seam was worked from No. 6 pit with longwall faces no less than 8 feet high. This working was carried on for a time below the sea without any accident. The roof of the seam often shows sections of the stumps of *Lepidodendra* and other carboniferous trees which are known to the miners as "pot bottoms" and rise up a short distance in the form of cylinders penetrating the overlying beds. These are converted into blackband ironstone enclosed in a ring of coal representing the original bark of the tree, and are apt to drop out if not carefully approached in working the seam.

(4) *Main Coal-seam.*—This is the best and principal seam in the section, and preserves a remarkable uniformity in character throughout the colliery. In quality, the Bridgeness Main splint coal-seam has few, if any, rivals among coals of this class in Scotland, as it has great heating power and contains little sulphur, water, and ash, and thus always commands a ready sale and fetches a good price in the market. The following analysis by Dr. Wallace, city analyst, Glasgow, shows the character of the seam in No. 6 pit:—

The analysis was made of the average of two samples taken from different parts of the pit, both being the full section of the seam, 3 feet 6 inches in thickness.

The analysis was as follows:—

Volatile matters—		
Gas, tar, etc.	30·77	
Sulphur	0·23	
Water at 212° Fahr.	2·04	
		33·04
Coke—		
Fixed carbon	64·21	
Sulphur	0·29	
Ash	2·46	
		66·96
		100·00
Coke (dry) per ton of coal		1,500 lbs., or 13 cwts. 1 qr. 16 lbs.
Specific gravity of the coal		1·282
Weight of a cubic foot		80 lbs.
Space required for storage (per ton)		42 cubic feet.

The analysis of the dry coke was:—

Carbonaceous or combustible matter	95·90
Sulphur	0·43
Ash	3·67
	100·00

The ultimate analysis of the coal was:—

Carbon	80·66
Hydrogen	5·37
Oxygen	7·62
Nitrogen	1·33
Sulphur	0·52
Ash	2·46
Water at 212° Fahr.	2·04
	100·00
Heat-units Centigrade from the combustion of the coal	7,964
Heat-units Fahrenheit from the combustion of the coal	14,335
Heating or evaporating power absolute in lbs. of boiling water converted into steam by 1 lb. of the coal	14·75 lbs.
Heating or evaporating power practical in the same	9·28 lbs.

The Main coal-seam varies from 3 to 4½ feet in thickness, and has a good roof of faikes and a daugh holing at most places, so that it makes an excellent working. The section is as follows :—

	Ft.	Ins.
Roof—Faikes	—	
Brushing—Faikes	3	0
Seam—Blaes	0	3
Coal	3	0
Daugh	0	2¼
Floor—Faikes	—	

The seam is all worked out to the rise in the immediate vicinity of the pit, but to the east there is still a large area to work. The eastern part of the field is, however, apparently interrupted by a volcanic neck that seems to cut off all the coal-seams in that direction, and until this interruption is pierced the good coal proved by boring to exist beyond cannot be easily reached. At present the Main coal-seam is entirely obtained from dip-workings by means of a dook driven in the seam from a point 260 feet west from the pit-bottom (Fig. 3, Plate VII.). The dook runs northwards, in line with the east wharf of Bridgeness harbour, and is almost 1,500 feet in length. The accompanying section (Fig. 1, Plate VII.) shows the inclination, which averages 1 in 5 near the top to 1 in 8 farther down, while at the northern extremity the seam is nearly flat, showing apparently that the strata, as indicated in the Parrot seam above, lie in a well-marked basin, into the centre of which the dook has been driven.

When the Main coal-seam was first worked in this pit, the pillar system was in vogue, the seam having never been worked on the longwall system before. It was at first a matter of considerable difficulty to get the miners to try working it longwall, but once fairly started the newer method was found by far the best, and it would now be as difficult a matter to induce the men to return to the old style of working. The bottom of the working is about 570 feet below high-water mark, and the seam is worked in fetches by levels driven at intervals, and headings running up the hill from which the branch levels run into the working places, as is shown on the plan (Fig. 3, Plate VII.). Except in brushing the roads, the seam is worked without explosives, the weight of the roof causing the coal when holed to burst out in large blocks. The full hutches are lowered to the level horse-roads by wheel-braes and cut-chains, and the haulage up the dook is effected by a compound beam-engine of the grasshopper type, but with the addition of a horizontal cylinder and surface-condenser.

This engine, which was designed by the late Mr. Cadell, is of a somewhat novel type. It works well, and a good vacuum is maintained by the water thrown up by the hydraulic pump at the bottom of the dook, which keeps the condenser quite cool, and prevents any exhaust steam from finding its way into the return air-course. The accompanying plans (Figs. 11 and 12, Plate VIII.) show the principal dimensions of this engine. The high-pressure horizontal cylinder is 10½ inches in diameter with 20 inches stroke, and the low-pressure vertical cylinder is 16 inches in diameter with a stroke of 27 inches.

Ventilation.—Although the Main coal is rather a fiery seam, naked lights have always been used, and no serious explosion has taken place in this pit, great attention having always been paid to the adequacy and efficiency of the ventilation. The air passes down No. 6 pit and returns to No. 5 pit, where it is exhausted by a Schiele fan, 8 feet in diameter, driven by a diagonal coupled engine capable of extracting 40,000 cubic feet of air per minute, under a water-gauge of 1·2 inches at 170 revolutions per minute.

Pumping.—Although the present and the old workings below high-water mark are tolerably extensive in area, the amount of pumping required is comparatively small. The first of the shore-pits on Grange (numbered from 1 to 4) were sunk on the beach at Grangepans, west of Bridgeness, between the years 1788 and 1798, to reach the Main coal and Six Feet seams. They were moated with clay to keep out the tide, and were known as "moat pits" at first.

No. 3 pit, sunk in 1789, is at present the pumping-shaft, and is fitted with a condensing Cornish beam-engine, with a cylinder 66 inches in diameter and 8 feet stroke, 16 inches plunger on the upper lift and a 15 inches bucket on the lower lift. This engine, which has been in operation for nearly 30 years, works exceedingly well, and drains all the submarine workings to a depth of 230 feet; but a considerable part of the water comes in above the rock through the walling which has been imperfectly puddled at first. As a rule, the engine can easily keep the water out by working one shift of 8 hours daily, but in wet weather and at spring-tides the water is somewhat heavier.

In the beginning of the century, an accident occurred in No. 4 pit, caused by an explosion, which set the workings on fire, and the only way to overcome the conflagration was to cut a channel to the sea and drown out all that part of the Grange colliery. The pits were allowed to remain

drowned till 1860, when they were again unwatered, and working was actively resumed by the late Mr. Cadell.

The water in No. 6 pit is drained by a plunger-pump with a 9 inches ram, which lifts the water from the Main coal-seam pit-bottom to the Red coal-seam level, 200 feet below the surface, the height of the lift being about 150 feet. From the Red coal-seam level, the water flows westward along a course of about ½ mile to No. 3 pit, where it is taken out by the large engine along with all the surface-water above that level.

The dip-workings are drained by a Moore hydraulic pump with a ram 8 inches in diameter, which works at 5½ strokes a minute and has a stroke of 3 feet. This pump has only lately been erected to supersede a series of Tangye special pumps that were formerly used and proved very troublesome to work, wasteful of steam, and costly to repair. The Moore hydraulic pump works admirably and goes continuously every day with scarcely any attendance. It throws the water up nearly 240 feet, and, as already stated, the water supplies the surface-condenser of the hauling engine before finding its way to the lodgment in the Main coal-seam pit-bottom. It is, however, proposed to pump the water direct to the surface in No. 6 pit, as no doubt some of it leaks back into the dip-workings on its way to the No. 3 pumping-shaft, and thus causes some needless work.

In proof of the water-tight character of the superficial clay-beds an interesting circumstance may here be mentioned. In 1869, some trial bores were made along the line of low-water mark east of Bridgeness pier at distances of 900, 1,800, and 2,880 feet respectively from the pier-head. While the boring was going on, the bore-holes in each case remained full of water, but as soon as the rock was reached the borers were surprised to find that the water left the tube, and, when the tide rose, ran down with a rushing noise, showing that all the strata which had been drained by the workings to the dip, some 2,700 feet distant, were quite dry and that the clay covering was perfectly impervious.

Conclusion.—Dr. Edward Hull, in his recently published interesting work, *Our Coal Resources*, expresses* the opinion that coal-mining under the Firth of Forth is impracticable on a large scale, on account of the danger from water. Bridgeness colliery is comparatively small and unimportant, but it is quite large enough to illustrate the important principle that where the superficial geological conditions are favourable, coal-mining under the sea is quite as practicable as coal-mining under the land. Indeed, the former possesses some advantages that the latter

* Page 81.

FIG. 1.

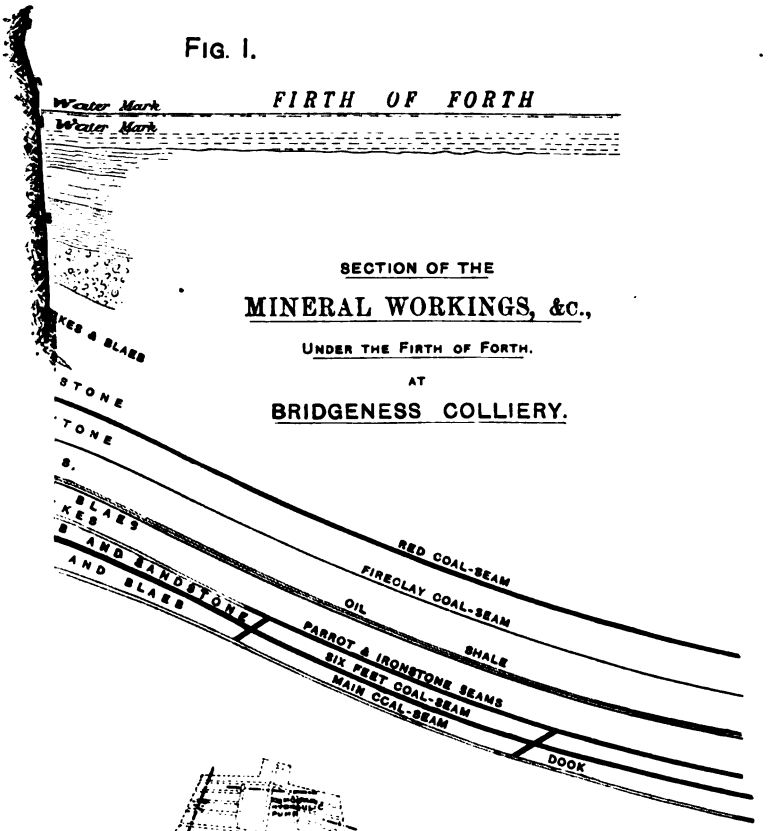

FIG. 6.

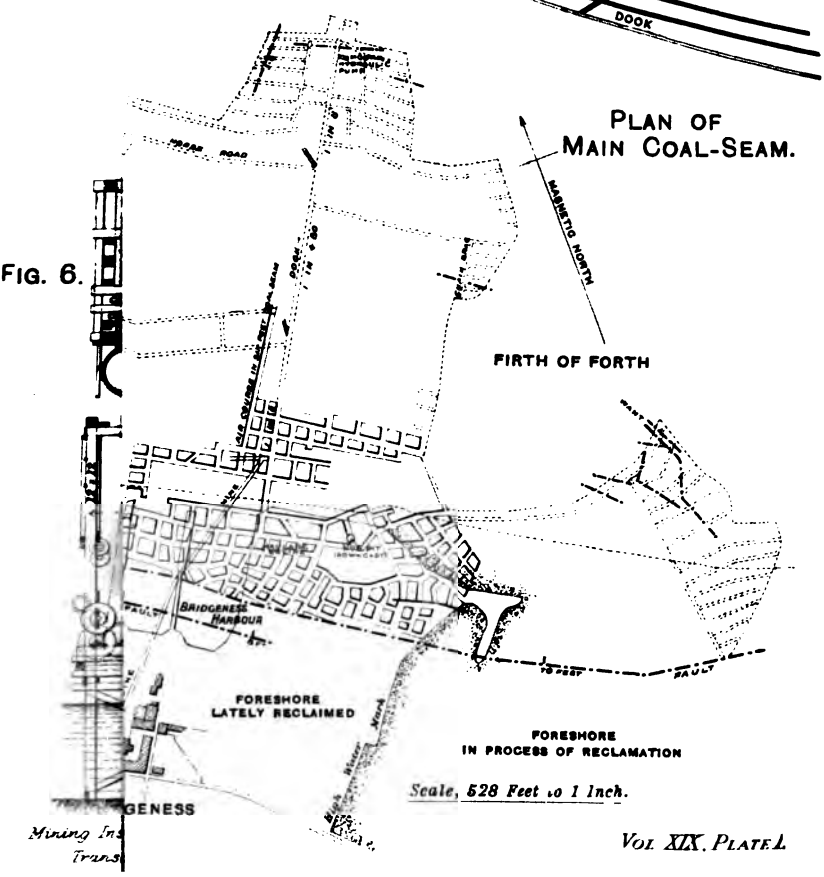

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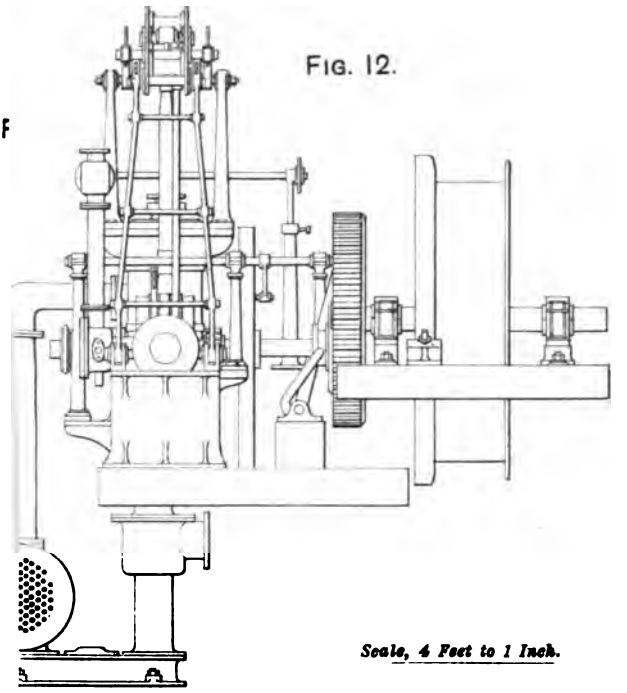
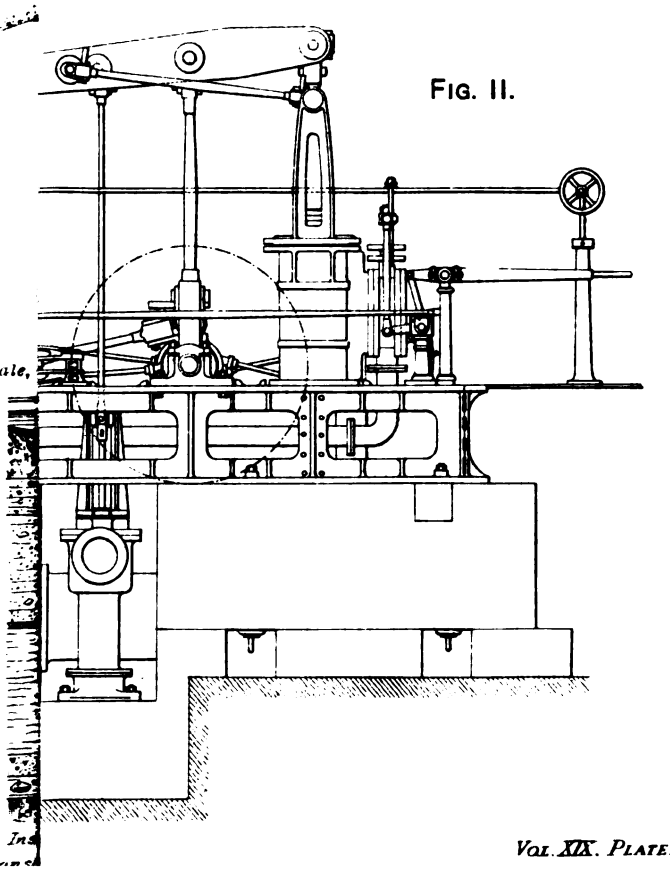
FIG. 12.



Scale, 4 Feet to 1 Inch.

FIG. 11.



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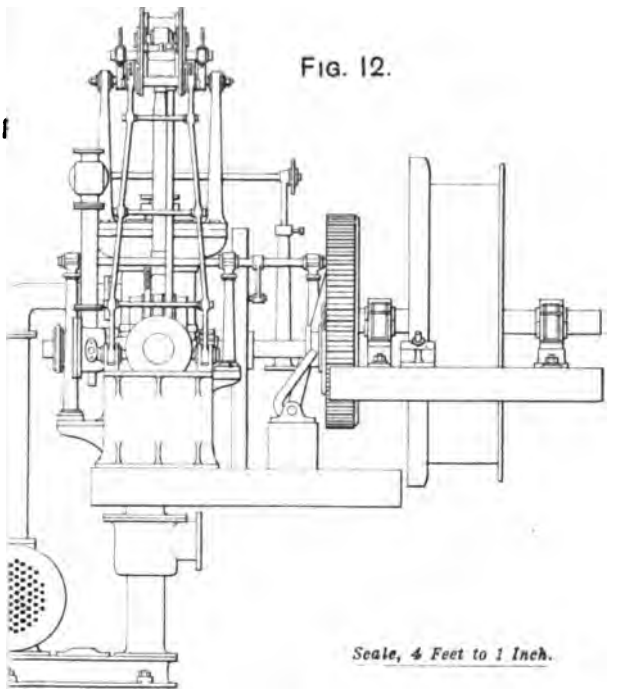


Fig. 12.
Scale, 4 Feet to 1 Inch.

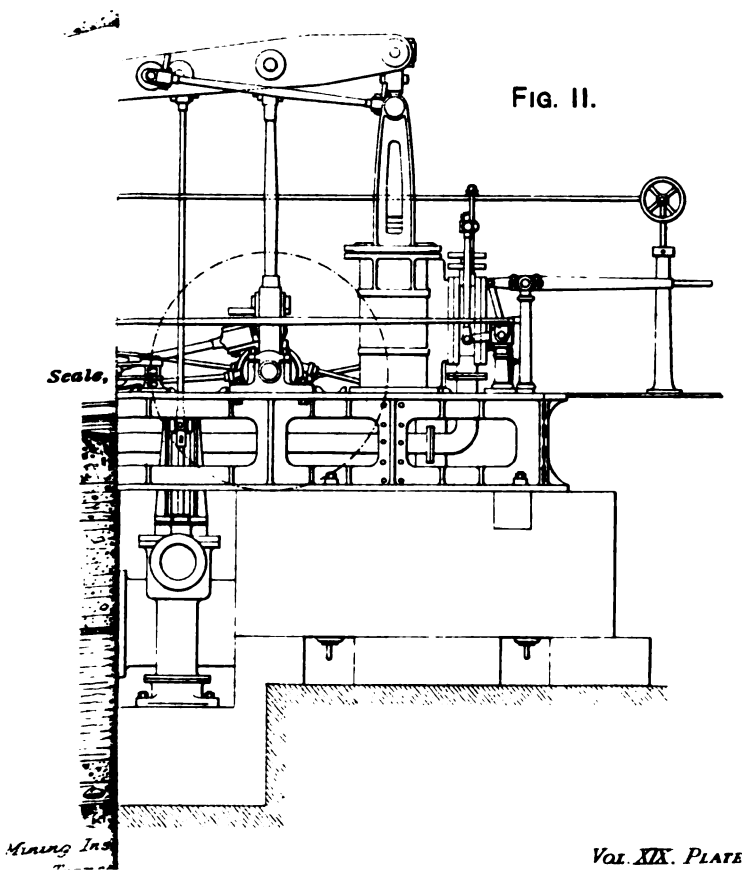


Fig. 11.
Scale,

cannot claim, one of which is that there are no surface-damages to pay to the owners of property above for subsidences, caused by longwall workings under the sea. The bed of the sea, which is here shallow, is on the contrary rather improved than otherwise by being thus deepened—dredged from underneath so to speak—to the advantage of navigation. Operations of late years have shown that seams can be worked on the longwall system under the sea, with faces 4 to 8 feet in height, at depths which are small in comparison with those of the workings in most modern collieries. The seams have been worked in three instances to their outcrop against the boulder clay, at depths from 137 to 400 feet below high-water mark, without any accident, and so long as these friendly deposits extend their protecting mantle over the valuable strata below, no danger need be feared in this district. The coal-seams below the sea opposite Grange estate, it may be mentioned, are not crown property, as the titles to the estate include the right of ownership of these deposits—a right that has been exercised for more than a century, and, the writer hopes, will continue to be exercised with profit for one more generation at all events.

Mr. T. E. FORSTER (Newcastle-upon-Tyne) said that Mr. Cadell referred to Prof. Hull's statement that coal-mining under the Firth of Forth was impracticable on a large scale, owing to the difficulties to be met with from water.* It would be interesting to know where Prof. Hull got the information upon which he based this inference. Mines were worked extensively on the northern side of the Firth of Forth and to some extent on the southern side, and he had never heard of the occurrence of water in the strata likely to cause any serious difficulty. The presence of the clay covering was an important factor, more especially as it was of a different nature from most of the boulder clays in the North of England. The thickness of the cover from which the whole of the deposits had been removed was less in this case than in any other he had seen in other parts of Great Britain. Mr. Cadell stated that there was only 137 feet of cover between the seam and the bottom of the sea.

Mr. J. B. ATKINSON (H.M. Inspector of Mines, Glasgow) said that the question of working under-sea coal would become a very important matter in Scotland. It was becoming of importance now on the shores of Fife, Haddington, and Linlithgow. The question would probably have to be considered before long, and something definite agreed on as to the conditions under which sea-coal should be worked.

* *Our Coal Resources*, page 81.

Mr. J. S. Dixon (Glasgow) said that there was a very valuable area of coal-fields lying under the Firth of Forth. A scheme was propounded by Mr. David Landale many years ago for a shaft to be sunk on the island of Inchkeith and work the coal on either side.

Mr. Cadell wrote that the overlying strata, which formed the roof at that place, were not solid in the popular sense, but consisted of the "till" or glacial boulder clay with the plastic red clay and river alluvium above it.

Mr. Dixon had referred to the late Mr. David Landale's proposal to sink a shaft on the island of Inchkeith, in the middle of the Firth of Forth, opposite Edinburgh, where the estuary was about 7 miles wide. He (Mr. Cadell) was well acquainted with the geology of Inchkeith, having, during the summer, made a geological map of the island for the War Department, who owned it. The idea of sinking a deep shaft, and driving a long crosscut from the bottom to reach the coal-seams of the basin on the east, was not, he thought, one that would commend itself to any practical mind at present. The rocks on Inchkeith were chiefly volcanic-trap beds, with sedimentary intercalations belonging to the Calciferous Sandstone or Lower Carboniferous series, below the Mountain Limestone, so that to cross into the productive Coal-measures an immense extent of tunnelling would be necessary. Again, the beds on Inchkeith were tilted up at angles of 45 to 55 degrees, and were not protected by a covering of clay, the bottom being at many places quite rocky round the island. There would thus be great difficulty from the influx of water, and the expense of reaching it, even if the existence of workable coal were certain, would be out of all proportion to the value of the coal when reached.

The Chairman, in moving a vote of thanks to Mr. Cadell, remarked that in one part of the paper it was stated that one advantage of working the coal under the sea was that they caused a depression of the land, and thereby produced a greater depth of water. He did not think that he would like to work so near the sea-bottom as to cause a depression sufficiently great to be of advantage for navigating purposes. Mr. Cadell had, however, shown that the clay covering the coal-seam was impervious to water.

Mr. James Barton read the following paper on the "Irish Channel Tunnel:"—

IRISH CHANNEL TUNNEL.

By JAMES BARTON, C.E.

In venturing to bring before the members of this Institution, the project for a tunnel between Scotland and Ireland, the author asks their forbearance, as a great subject is necessarily dealt with by this paper in a preliminary way.

It would seem most in accord with the objects of the Institution to pass by here the great considerations of trade and passenger travel, which have latterly come prominently forward as reasons for such a project being taken up. These considerations largely affect Scotland, as they do Ireland; nor would it be proper to consider the political advantages however important; nor the financial results of investment in the project; nor the desirability or the contrary of its being from the first controlled by government, and made a highway for the various railways which would concentrate upon it upon both sides of the Irish Channel.

The following paper deals solely with the engineering aspects of the question, and may perhaps have the good fortune to elicit discussion, and bring out the results of experience from members of the Institution.

I.—*As to the Route to be Adopted.*—The selection of the route is, practically speaking, confined by the conformation of the coast-line to a selection along the Mull of Galloway on the Scotch side and the coasts of Antrim and Down on the Irish side.

The advantages of a tunnel under the narrower channel between Ireland and the Mull of Cantyre are so small, by reason of its position, that by general consent it is felt that no great public gain worthy of a large outlay could be attained there; whilst a tunnel which, with its approaches would connect Belfast with Stranraer, would give a good railway-connexion from the whole of Great Britain with the north of Ireland, and would similarly give an excellent communication from the whole of Ireland with Scotland and the north of England.

The conformation of the sea-bed in this portion of the channel is the first important factor in determining the route. Mr. Ormsby, M. Inst. C.E., between 1860 and 1870, proposed a tunnel from Donaghadee to Portpatrick: the length from shore to shore by that route is 21 miles, but it involved crossing a depression in the sea-bottom called Beauforts Dyke,

where the water is 900 feet deep, and he met with littte encouragement. The dotted line marked No. 4 route on Plate IX. is probably not very far from his proposal. Mr. McCullough, M. Inst. C.E., has written letters in the newspapers advocating a line from Whitehead on the Antrim coast to Portpatrick on the Wigtonshire coast; this line crosses the Beauforts Dyke, but at a place where it is not so deep as the route first mentioned; this route (as nearly as known) is shown as No. 3 route on Plate IX.

The No. 1 and No. 2 routes (Plate IX.) are alternative routes proposed by the author in conjunction with Messrs. Hawkshaw and Hayter; they both start on the Irish coast from a promontory called Island-Magee on the coast of Antrim, and run direct for a point north of the Beauforts Dyke depression, where the depth of water is about 500 feet, and north of the place where the sudden dip of the Beauforts Dyke commences curving. Thence with a curve of, say, a mile radius, a straight line runs by Portobello under the high ground of the Mull of Galloway, and comes out of the tunnel, where the hill drops steeply down to Loch Ryan. Two routes are shown, and No. 1 is a slight improvement in the author's opinion over No. 2 route, and would cost rather less money.

The four plans (Plate IX.) and sections (Figs. 1, 2, 3, and 4, Plate X.) are laid down for comparison on similar gradients, with a similar depth of 150 feet below the sea-bed to the top of the tunnel; and estimates have been framed for each, at similar prices, where the work is the same.

For the purpose of drainage, it is necessary to have a fall to the shore-ends of the tunnels, and this is to be effected by headings (shown on the diagrams) which convey the water to the sumps at the shore-shafts where the pumping-engines would be placed, this is carried out similarly in each of the four sections (Figs. 1, 2, 3, and 4, Plate X.).

The drainage-headings perform an important part in the ventilation alluded to lower down. Members will perceive that the depth of the shafts and the length of the extra headings in Nos. 3 and 4 routes are considerably more than in Nos. 1 and 2 routes. They stand approximately thus:—

	No. 1 Route.	No. 2 Route.	No. 3 Route.	No. 4 Route.
Length of tunnel under sea, miles ...	24	25	23	20
Total length of tunnel, miles... ...	34	35	34	32
Length of headings not in tunnel, miles	10½	12	12½	18
Depth of pumping-shaft, Irish side, feet	720	740	750	1,040
Do. do. Scotch side, feet	740	740	1,035	1,130
Length of railway to construct to junctions, miles	7¼	5¾	1½	2¼

The author considers that the crossing of the tunnel under the deep-sea valley involves much more than the question of comparative amount of work to do; he and his partners further consider that the likelihood of having special difficulties to deal with would be largely increased by having to go to so great a depth, and one of these is in connexion with the material on the surface of the sea-bed. The bottom of the channel has been sampled in a rather extensive way by the Hydrographic Department of the Admiralty, and they have found it to be a sediment composed chiefly of ooze, shells, fine mud, and sand.

This bed is too deep to be affected by storms, and it is probably but little affected by tidal currents, which at their strongest run from 1 to 2 knots per hour. It is the cemetery and refuse-place of the inhabitants of the channel, so far as the tides permit the deposition, and a certain amount of material comes from the rivers and shores, carried to sea probably for long distances in time of storm, and gradually dropped. This material, it appears to the author, may have gravitated through the long period since the Beauforts Dyke was formed gradually down the sides of the dyke, and be lying to a great depth in its bottom; and as it would be very difficult, if not beyond us, to ascertain by boring the depth of such a filling at so great a depth, it would be a very serious risk to assume 150 feet as a safe cover to the tunnel in this dyke, though safe in the normal and comparatively level portions of the sea-bed.

The author has devised apparatus by which he hopes to be able to take borings along the line of No. 1 and No. 2 routes, in water of a maximum depth of 500 feet, to ascertain the depths of soft sea-bed to the surface of the solid rock, and to ascertain the nature of the rock, so as to say with confidence what the tunnel will pass through at certain depths; but to do this in 800 or 900 feet of water would be a very different thing.*

II.—*Geology of the Channel.*—A geological map of the United Kingdom shows the Lower Silurian formation on the surface for a width of some 30 miles, extending in a south-westerly direction from Selkirk and Peebles through Dumfries and Wigton to the shore at the Mull of Galloway; and on the Irish side the same formation is continued across County Down and parts of Louth and Armagh. In Antrim, it is overlaid by the New Red Sandstone, which again is generally covered by Red Marls. These are on the surface north of Belfast Lough; but for the most part of the county of Antrim they are covered on the surface by the

* Since this paper was read, the writer has received a definite proposition for these sea borings in water up to 500 feet deep, from an experienced firm of borers.

tabular formation of trap rock. In Antrim, the Chalk and Greensand in thin beds are also found overlying the Red Marls, being visible on the coast at Whitehead and other places near that place.

The probable lie and extent of the strata under the channel have been laid down by Prof. Hull (lately head of the Geological Survey of Ireland); they are shown upon the sections in Figs. 1, 2, 3, and 4 (Plate X.), and he has given his opinion that the data obtained from the strata on each side of the channel are sufficient to enable him to arrive approximately at a fair estimate of the nature of the rocks and the strata to be encountered in making the tunnel He stated that he was perfectly satisfied that there were no geological difficulties likely to be encountered in the construction of the tunnel which engineering skill would not be able to meet.

The outcrop of the junction between the New Red Sandstone and the Silurian formations would be (Prof. Hull stated), if on land a probable layer more or less pervious to water, but as it had been for ages gradually under the process of sealing by sea-deposit and under great pressure, he did not believe that it would be found a danger, whilst the advantage of tunnelling through the marls and sandstone for several miles would largely facilitate and cheapen the tunnel-excavation.

The late Mr. W. Topley, of H.M. Geological Survey, London, a well-known geologist, confirmed these views.

Experience of sub-aqueous tunnelling goes to show that the chief dangers of water lie in the approach-tunnels rather than in the portion situated under the bed of the sea or river. In the former case, all crevices remain open, those above the level of low water being channels by which water is carried downwards and thereby kept open; whilst those in the sea-bed during past ages have been gradually sealed up by sea-deposits, and that under heavy pressure, which would gradually drive out air and water and tend to caulking of all joints. The author's opinion on the subject is strengthened by the fact that in the Mersey and Severn tunnels no leakage occurred under the river-beds; and the great spring which was such a difficulty at the Severn tunnel was fresh-water, and under the land portion of the tunnel.

The late Sir John Hawkshaw, whose firm were engineers to the Severn tunnel, said that :—

> A tunnel beneath the sea, if only deep enough down, was just as likely to be dry as a tunnel beneath the land.

Sir Douglas Fox, engineer to the Mersey tunnel, said that :—

> When the tunnel was commenced apprehensions were very general as to the

danger of the water coming in through fissures, of which it was surmised the strata cut through would be full. As a fact, only one fissure was encountered, and that was certainly drier than other parts of the work.

Sir Benjamin Baker said, on this subject,* that :—

A headway was driven under the Forth a mile, and at Whitehaven ½ mile under water; in both cases, as in that described by Sir Douglas Fox under the Mersey, they found less water under the sea than under the land portion of the work. He thought that might be taken as practically proved to be generally so in rock strata; and the fact had an important bearing upon any future contemplated submarine tunnel, such as a Channel tunnel, or a tunnel to Ireland perhaps.

The Red Marl, in the neighbourhood of where the tunnel would commence in Ireland, has had shafts sunk in it for salt, which occurs in pockets. The author has been down one of these shafts to a depth of 900 feet in these marls, and found the bottom absolutely without water, no pump being required except near the top of the shaft for the surface-water. This shaft, at its bottom level, would be probably 500 feet below sea-level. The marls were an easily-quarried, solid, slaty rock, the lower strata being hardest.

III.—*Estimates.*—Estimates at this stage are preliminary, but the experience gained from Alpine and other tunnel-borings go a considerable way in enabling those who have carried out large works to form a sound judgment on the data as far as they go, and these estimates help one to form a correct opinion as to the comparative desirability of different routes.

The estimate for No. 1 route on the diagrams is £8,400,000.

For No. 2 route, £8,600,000.

For No. 3 route, assuming that it is not necessary to go to an extra depth below the present sea-bed, nor allowing any sum for extra risk for the crossings of the Beauforts Dyke, £9,200,000.

For No. 4 route, on the same basis as above for No. 3 route, £9,900,000.

Taking the estimate for No. 1 route, the author and his partners consider that special contingent expenses being probable they should state the cost as between £8,000,000 and £10,000,000.

IV.—*Completion of Work.*—In considering the probable time for completing such a tunnel, let us note a few of the long tunnels already made. Probably the longest completed tunnel is that at Schemnitz in Hungary, used as a channel for water from the mines to the Grau

* *Trans. Inst. C.E.*, vol. lxxxvi., page 91.

Valley—its length is 10¼ miles, its section 10 feet by 5 feet 8 inches, and it was commenced in 1796, but not completed until 1878. The first portion for several years was contracted for at £7 per yard, but afterwards it cost much more, and the total cost was about £1,000,000.

The Mont Cenis, the first Alpine tunnel, is 8 miles long, its progress, after compressed-air drills were introduced, was as a maximum 6 yards per day, but averaged only 2½ yards. The cost of that tunnel was £224 per yard.

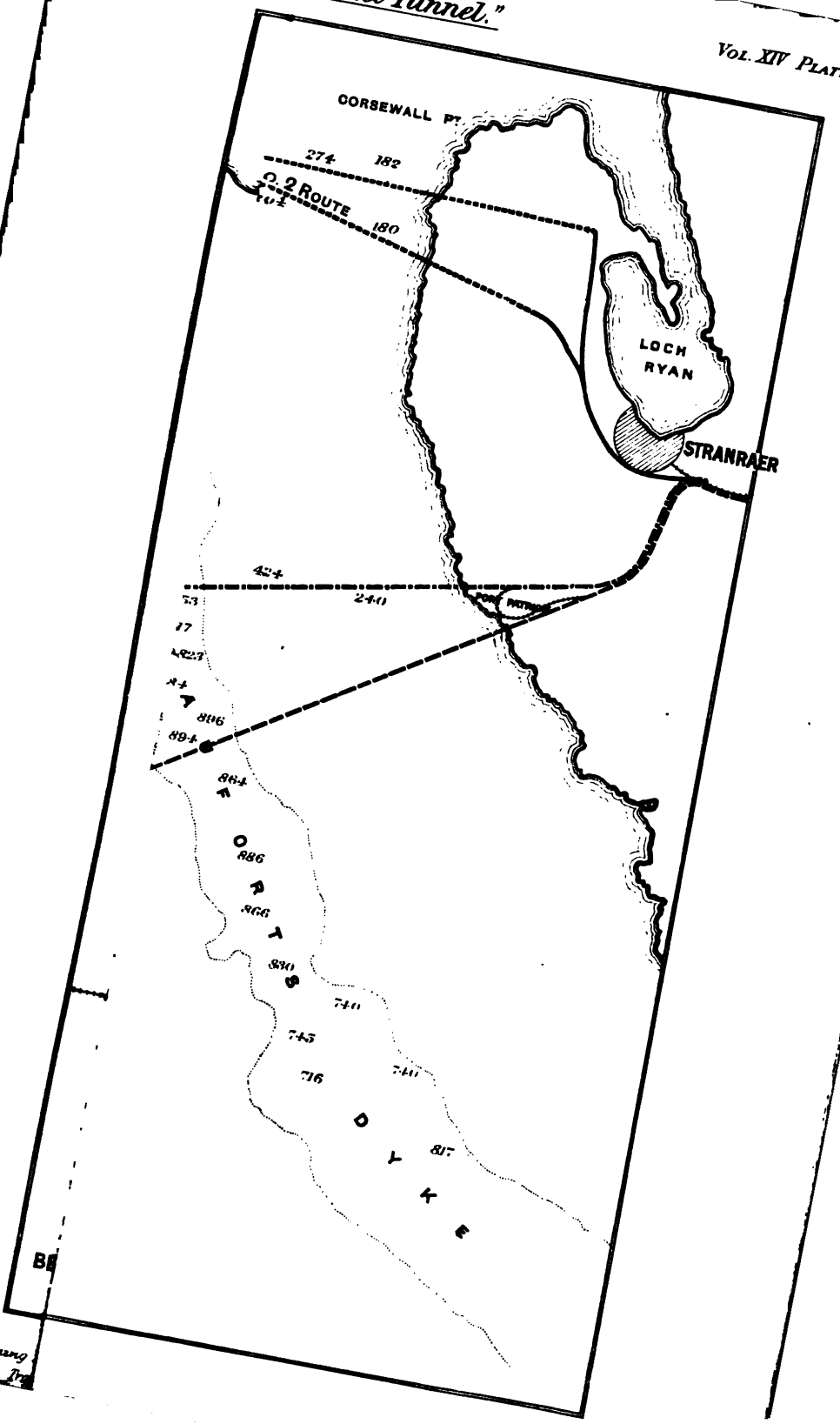
The next was the St. Gothard tunnel, 9¼ miles long, commenced in 1872. Its progress, commencing at 2½ yards per day in 1872, rose to 10 yards per day in 1880, the strata being granite, schist, and gneiss. It was completed in 7½ years, and its cost was £142 per yard, a great decrease from the Mont Cenis cost of £224 per yard.

The third was the Arlberg tunnel, commenced in 1880. The length of this tunnel is 6⅓ miles, the time of completion about 3 years, and the rate of progress, commencing at 7 yards a day, increased to nearly 12 yards, the rock pierced being schist and quartz. This tunnel cost £1,200,000, and its cost per yard is about £107.

The Simplon tunnel will be between 12 and 13 miles long, and there again an increase of speed is expected upon those made before it.

The estimates above given for the Irish Channel tunnel include £125 per yard for the tunnel in Silurian rock, and £102 per yard in the marls and sandstones, adding to these prices the cost of pumping and ventilating-machinery, and the cost of shafts, etc., and the time would probably be from 10 to 12 years.

V.—*Ventilation.*—The question of ventilating such a tunnel, if the trains are worked by ordinary steam-engines, has been practically dealt with in a paper by Mr. Clark Hawkshaw, read before the British Association for the Advancement of Science, in reference to the then proposed tunnel from England to France—the length to be ventilated being nearly the same as in this case. The amount of gases which has to be removed is known from the quantity of coal which would be consumed in the production of the power to work an estimated number of trains per hour; the amount of dilution of those gases to render them innocuous is then ascertained; suitable engines will then discharge by fans, or otherwise, the necessary amount of pure air down the shafts and along the drainage-heading, and then by closed channels under the permanent way and separate from the main tunnel, and discharge the air near the centre of the tunnel, from which two air-currents would pass back to the ends.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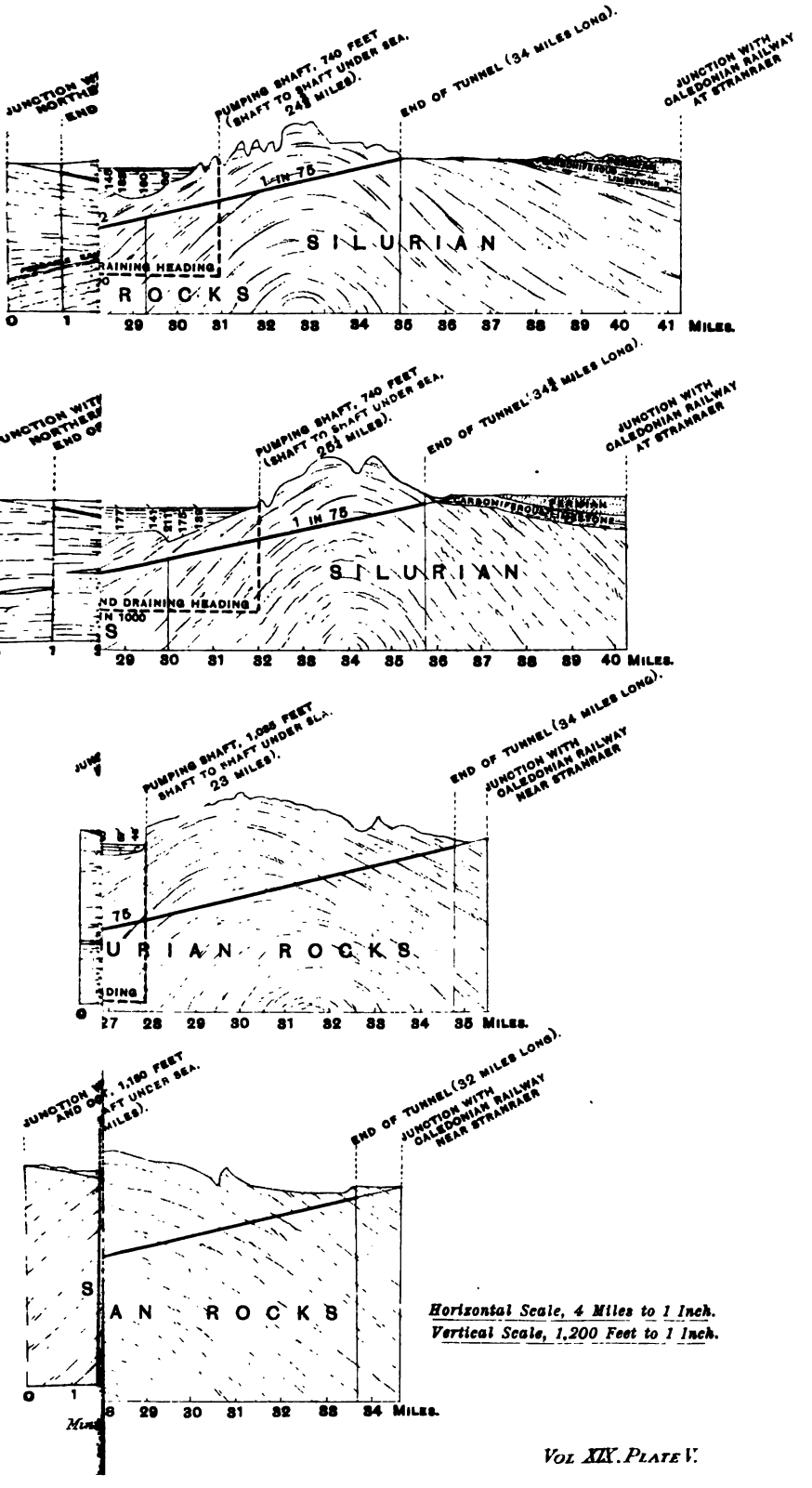
JUNCTION WITH NORTHERN END
PUMPING SHAFT, 740 FEET (SHAFT TO SHAFT UNDER SEA, 24½ MILES).
END OF TUNNEL (34 MILES LONG).
JUNCTION WITH CALEDONIAN RAILWAY AT STRANRAER
1 IN 75
SILURIAN ROCKS
DRAINING HEADING
0 1 29 30 31 32 33 34 35 36 37 38 39 40 41 MILES.
JUNCTION WITH NORTHERN END OF
PUMPING SHAFT, 740 FEET (SHAFT TO SHAFT UNDER SEA, 26½ MILES).
END OF TUNNEL (34½ MILES LONG).
JUNCTION WITH CALEDONIAN RAILWAY AT STRANRAER
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PUMPING SHAFT, 1,095 FEET (SHAFT TO SHAFT UNDER SEA, 23 MILES).
END OF TUNNEL (34 MILES LONG).
JUNCTION WITH CALEDONIAN RAILWAY NEAR STRANRAER
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URIAN ROCKS
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JUNCTION WITH 1,150 FEET AND OF SHAFT UNDER SEA. MILES).
END OF TUNNEL (32 MILES LONG).
JUNCTION WITH CALEDONIAN RAILWAY NEAR STRANRAER
AN ROCKS
0 1 28 29 30 31 32 33 34 MILES.

Horizontal Scale, 4 Miles to 1 Inch.
Vertical Scale, 1,200 Feet to 1 Inch.

The difficulty of ventilation will, however, be immensely diminished by the use—as the author expects—of electricity as the motive power, which is even now capable of such an application, but which will doubtless be capable of application in better detail a few years hence.

The approach-tunnels could be shortened and the estimated cost thereby reduced by steeper gradients; but, considering the very large traffic which may be anticipated, a maximum grade of 1 in 75 has been assumed for the present.

VI.—*Soundings.*—The next step in the project are accurate soundings at much shorter intervals than those which have been taken, also surveys and levels to obtain absolutely the distances and levels across the channel. Core-borings also are necessary at the sites of the shore-shafts to the full depth, and deep-water borings as already referred to, to ascertain the depth of soft deposit on the rock under the sea-bed and the nature of that rock.

These preliminary matters will cost probably £15,000, and when these are settled it will be possible to speak with increased confidence as to the advisability of further expenditure.

The next expenditure, in the author's opinion, and that of Messrs. Hawkshaw and Hayter, would be to sink the shaft on the Irish side and carry a heading so far as to pass the junction between the New Red Sandstone and the Silurian formations (this would cost £200,000 or £250,000), after which the risks would be minimized and the work would thenceforward be one, the cost and time for execution of which could be closely estimated.

Very influential committees have been formed in Great Britain and Ireland to carry forward the project. They think that the preliminary expenditure (at least) should, for such a national benefit, be found or guaranteed by the state, and the author ventures to suggest that some leading men of Scotland should join the London committee in their efforts to push forward this work.

Prof. Edward Hull (late Director of the Geological Survey of Ireland) wrote that Mr. Barton had in his paper so fully expressed his (Prof. Hull's) views on the geology of the proposed tunnel that little remained to be added on this occasion. It was clear that in the absence of detailed submarine experiments, such as the author had suggested, our

knowledge of the nature of the submarine rock-bed must be founded upon that of the bordering land-surfaces. Speaking generally, a survey of the coast, both on the Irish and Scottish sides of the North Channel, leads to the conclusion that there are only two sets of formations to deal with, namely, the soft sandstones and marls of the Triassic system on the Antrim side, and the Silurian rocks on the Wigton side. These latter consist of hard green, grey, and purple grits and slates, traversed by dykes of trap. The former would be very easily and cheaply pierced by boring machinery, the latter would offer greater resistance, but not excessive. He thought it probable that the Traissic strata would be found to extend to about 3 miles out to sea from the coast of Island-Magee, and that the Silurian beds would form the remainder of the tunnel. What the nature of the junction of the two formations may be, it is impossible to say at present; it may be a line of fault, or simply an overlap. He fully concurred in the opinion of the author, supported as it was by Messrs. Hawkshaw and Hayter, that one of the preliminary trials should be that of a shaft and a heading driven out from the Antrim coast in order to pass through the junctions of the two formations and thereby to solve the questions of the nature of the junction, and of the quantity of water likely to be met with at that point. The proposal before the Institution was one of such great international importance, and calculated to be of such great commercial advantage to both countries, that he could not doubt but that it ought, and would, receive assistance from H. M. Government when they have fully considered the whole subject, with such details as the eminent engineers who have taken it up are well able to afford.

Mr. M. H. Mills (Nottingham) said that it must strike them as mining engineers that the expense of the work seemed enormous for what had to be carried out. It was hardly necessary, in the first instance, to sink shafts and drive out those headings to the deep. He also thought that in such an undertaking there was not perhaps a necessity for so large a tunnel as Continental railway-tunnels. If compressed air were used, and only a single road made, the drift would then cost very much less than Mr. Barton had calculated. Mr. Barton appeared to have taken his views of expense from the cost of Continental tunnels, many of which were curved and corkscrew, and this added very materially to their cost. In the Silurian slate-mines in Wales, they had not experienced any great difficulty with water. There might, of course, be water in the New Red Sandstone, but Mr. Barton had shown that there was no great amount of water in the marls.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that it was quite possible that large volumes of water would be found in the New Red Sandstone when driving across the measures, which was rather different from driving along them, as was proposed in the case of the Channel tunnel. The quantity of water would also depend on what might be found at the junction of the New Red Sandstone and Marls and the Silurian rocks, and the shape of the sea-bottom. Until borings were made, it would be premature to give any opinion as to the quantity of water to be met with. He was not quite sure from what Mr Barton said, whether allowance had been made in the estimates for the probable amount of water to be pumped.

Mr. R. T. Moore (Glasgow) said that one of the advantages of a tunnel of this kind would be to avoid transshipment of goods in taking them from England to Ireland; but had Mr. Barton taken into consideration the fact that the railway-gauges in the two countries differed?

Mr. J. Charles King (London) wrote that the importance of a closer connexion between Great Britain and Ireland claimed the earnest consideration of the inhabitants of the United Kingdom. At present steamboats furnish the transit from land to land with commendable facility and at economical rates. Whatever method of junction of the separated islands may be adopted, the waterway will ever be a cheap, and to many wayfarers an attractive, way of travel. Except one other tunnel scheme, the several propositions for uniting the two countries have been ignored for one particular scheme, which it is proposed shall be carried out at a depth of 150 feet below the bed of the sea. Nothing has been said about the possible occurrence of seismic tremors rupturing the tunnel and leading to its destruction, or of the cost of casing the tunnel to exclude leakage of water. In a previous similar paper on Irish tunnel schemes read before the Royal Society of Arts, London, Mr. Barton admitted that a channel-tunnel undertaking could not be solvent without a subsidy annually from the Government; but as that is not likely to be forthcoming, it is desirable to describe a much older project made by himself (Mr. J. Charles King). He had made a life-study of the junction of the separated islands, and was fully acquainted with the topography and hydrography of the Irish Sea. His (Mr. King's) views are, that whatever project may ultimately be adopted it should be solely a national enterprise, and that the Government should carry out the requisite works. His project is for an isthmus to be made at the narrowest part of the North Passage, 12½ miles across, and of an

average depth of about 300 feet, so as to form an open causeway about 300 feet wide at the top. In suggesting an isthmus as being the most desirable junction, his (Mr. King's) further aim is to stop the inflow of the gulf-stream from the north so as to prevent it flooding the Irish Sea, as now, and thus he would automatically reclaim about 1,000,000 acres of useful land from the coast-loughs of Ireland, and the foreshores of both the eastern and western coasts of the Irish sea, making it an island-studded lake or inland sea for its main area. For ship-passage out of and in to the Irish Sea from the north, he proposed that a sea-level canal, 6 miles long, should be made at Campbelltown, in Cantyre, and Machrihanish Bay in the North Passage, and another sea-level canal, 1 mile in length, from Loch Fyne at Tarbert to West Tarbert Loch. The expense of an isthmus-junction would be between £2,000,000 and £3,000,000, if convict labour mainly was used on the work. He (Mr. King) pointed out that the materials suited for the undertaking exist in unlimited supply on the two adjacent coasts. He believed that the work could be completed in three or four years, but deprecated haste in its erection.

Mr. Ernest Benedict (London) wrote that Mr. Barton's paper was a valuable contribution to the enormous mass of literature on the subject of Channel crossings, which the writer studied some years ago in connection with Sir Bradford Leslie's well-considered scheme for spanning the English Channel with a floating steel-tube, held down at a safe distance under the surface of the sea. The writer was also greatly interested in the Severn tunnel, originally designed by his old master, the late Mr. Charles Richardson, and in the difficulties experienced through land-springs on the Welsh side of the tunnel, of which difficulties Mr. Barton seems fully aware. He is, perhaps, rash in venturing to disagree with Mr. Barton's conclusions, backed as they are by such eminent authorities; still he is strongly inclined to prefer No. 4 route, and for the following reasons:—(1) The tunnel passes straight across the Channel, and between the shafts; (2) the route is the shortest, saving some miles of construction both of tunnel and of junction-railways, and a considerable amount of running, not only over the new lines, but over existing ones; (3) the tunnel is in rock throughout, thus avoiding the doubtful part through the marl, chalk, and basalt. That Mr. Barton had doubts as to this part of his project, is shown by his proposal to begin operations by sinking the shaft on the Irish side and carrying "a heading so far as to pass the junction between the New Red Sandstone and the Silurian formations, after which the risks would be minimized." As to the chance of finding water 150 feet under the Channel-bed in the

Beauforts Dyke, the writer cannot but think that this is a remote one; for whatever the composition of the bed, it must have become thoroughly consolidated by the pressure of 150 feet of earth, topped by 900 feet of water, or say, over 30 tons per square foot, and that for ages past. Except in the case of the Beauforts Dyke, Mr. Barton is emphatically of this opinion. Besides, the writer does not believe that the difficulty of boring in 900 feet of water is insuperable, and would suggest the employment of large double or jacketted pipes, weighing less than the water displaced, which could be ballasted, as required, by introducing the necessary amount of liquid in the annular air-space surrounding the inner tube. Similar pipes were successfully used by Sir Bradford Leslie in boring out the cylinders of the Gorai bridge in Bengal. Mr. Barton does not state whether his estimate is for a single or for a double-line tunnel. If electricity be used for propelling the trains, ventilation would be so easy that the tunnel might be constructed of the smallest possible dimensions necessary to take standard rolling stock. In view of the great tide-power available, it would appear as if all the electrical energy for moving the trains, for pumping the water, and for ventilating the tunnel might be generated on either shore, near the two shafts. Part of this plant might be utilized for drilling and ventilating the shafts and the two drainage-headings. Additions could be made to the power as the works advanced; and all the operations required during construction might be driven thereby. If communication by rail between Great Britain and Ireland could be obtained for £10,000,000, it would be cheap at the price; but in the present state of the money market it is doubtful whether that amount could be raised; and it is out of the question to ask the government to spend the money in view of the very great and necessarily increasing expenditure on our naval and military defences.

Mr. BARTON, in replying to the discussion, said he was aware that the railway-gauge in England was 4 feet 8½ inches, and in Ireland 5 feet 3 inches, and there were several 3 feet gauge-lines in Ireland also. A large part of the traffic would, in the first place, be passenger, and it would come out at Belfast, which it was proposed to make the terminus of the tunnelled railway; then they would have a transshipping-station in Ireland for goods going beyond Belfast until the traffic became large enough for existing lines to lay down a third rail for English railway stock; Belfast, however, would by its merchants be the distributing-station for all kinds of traffic, and in this way the disadvantages of a change of gauge would be avoided. The question of having a shaft and headings for ventilation on each shore was an important one, especially

if they were obliged to have ordinary locomotive-haulage. In reply to the question as to whether the cost of pumping had been included in the estimate; they had in the first place an item of £200,000 for pumping and ventilating machinery and the percentage added for contingencies was also very large.

On the motion of the president, a cordial vote of thanks was passed to Mr. Barton for his paper.

Mr. JAMES BARROWMAN (Hamilton, N.B.) read the following paper on "Slavery in the Coal-mines of Scotland":—

SLAVERY IN THE COAL-MINES OF SCOTLAND.

By JAMES BARROWMAN, Mining Engineer.

It is not necessary that the records of the dim and distant past be searched in order to find a condition of things answering to the title of this paper. Not a hundred years ago, a system of servitude still existed in Scotland, sanctioned by the practice of two centuries, by virtue of which colliers and their families were fixed to the soil almost as effectually as if they had been bought in the slave-market of New Orleans or born in the hut of a negro on some Virginian plantation.

It is matter for surprise that such an institution should have been allowed to exist in Scotland, and our surprise is not lessened when on enquiry it appears that it was not a relic of the social system of the Middle Ages, but was the result of express enactment by the Scottish Parliament.

In the early centuries of our country's history, while yet the forests were extensive and wood abundant, there was little need for coal, and it was therefore not much sought after for domestic purposes. Perhaps the first use to which it was applied to any considerable extent was in the manufacture of salt from sea-water, as we find that the earliest coal-works were on the seashore, and usually associated with salt-pans. Saltmaking, being capable of continuous operation, required a regular supply of coal, and so these industries of saltmaking and coal-mining grew up side by side and interdependent. The early coal-workings were of a superficial character, being chiefly of the nature of quarries; indeed, the primary meaning of the word heugh—the name given in past times to a coal-pit—is a steep bank or glen. The labourers on the coal-producing estates, assisted by the members of their families, performed the work when it suited their convenience. The extension of the workings below the surface of the earth as the open diggings became exhausted, coupled with the increasing demand for coal and salt at home and abroad, necessitated more extensive, systematic, and continuous working, and in this way coal-mining came to be a regular craft, not much sought after by outsiders, but providing ready and profitable occupation for the collier and his family, the father and elder sons hewing the coal and the daughters and younger sons—and not seldom the mother also—bearing it in baskets on their backs from the coal-face to the pit-mouth.

The collier and his dependents were subjected to a measure of social ostracism, partly on account of the spirit of the times, which in a much greater degree than now regarded all labour as menial, but chiefly because of the solitary nature of the occupation. Engaged in dirty and unattractive work, in darkness and alone, and dissociated from the activities of the outer world, the collier settled into that condition of separateness which is characteristic of the class to the present day.

Such was the state of the coal-mining population in the sixteenth century, when the country was awakening to a sense of its commercial capabilities. Successive Acts of Parliament passed in the later years of that century to prohibit the export of coal are evidence of the rise of an extensive trade with foreign countries, the wider development of existing coal-works, and the opening up of new fields to meet the demand. The owners of new coal-works, having no trained colliers on their own estates, sought them at established collieries, and induced them by means of gifts and promises of higher wages to leave their employment. This was naturally resented by their masters, who had difficulty in getting sufficient workers for their own pits. The aggrieved coal-owners made application to Parliament to put a stop to the practice. Accordingly, in the year 1606, an Act was passed, which ordained that no person should fee, hire, or conduce any salters, colliers, or coal-bearers without a sufficient testimonial from the master whom they had last served, and that any one hiring them without such testimonial was bound, upon challenge within a year and a day by their late master, to deliver them up to him, under a penalty of £100 for each person and each act of contravention, the colliers, bearers, and salters so transgressing and receiving wages to be held as thieves and punished accordingly. Reference has already been made to the close connexion between colliers and salters, which explains why salters were brought within the scope of this Act.

It need not be supposed that this measure did violence to the sentiment of the time, or that the workers thought it an instrument of oppression. It had been the rule for the collier and his family to live and be cared for and die on the estate on which he was born, and the mere preventing him from leaving the work where he was engaged, unless he had the permission of his master, would probably appear to him to be no unreasonable restriction.

Primarily designed to prevent desertions, the Act was ere long found to have a farther reach than its framers probably dreamt of. It authorized a coal-owner to retain his colliers as long as he had work for them. From the fact that many collieries were then in constant opera-

tion, and that some have worked continuously to the present day, it is apparent that the colliers attached to works of a permanent character were bound for life, and from generation to generation. And even in the case of collieries where work was not continuous, the worker found that he could not oblige his master to give him a testimonial on leaving, and that he was liable to be recalled as soon as work was resumed. Indeed, it appears to have been the rule for masters to withhold a testimonial, in order that they might the more freely reclaim when need arose.

Up till the year 1661, colliers and salters were the only workers to whom the Act applied, but in that year the Act of 1606 was ratified, and an addition made embracing other colliery workers—named watermen, windsmen, and gatesmen. This circumstance furnishes incidentally a noteworthy proof of the great progress that had been made in mining during the preceding half century. Departments of work that formerly did not exist, or were merely subsidiary, had become specialized; and there were now men in the collieries set apart for laving or pumping water from dip-workings, winding the coal up the shafts by means of windlasses, and attending to the repair of the roads underground.

An Act passed in 1672, for the establishment of correction-houses for idle beggars and vagabonds, authorized "coal-masters, salt-masters, and others, who have manufactories in this kingdom, to seize upon any vagabonds or beggars wherever they can find them, and to put them to work in the coal-heughs or other manufactories, who are to have the same power of correcting them and the benefit of their work as the masters of the correction-houses." We need not conclude that the ranks of the colliers were largely reinforced in this way. The sturdy beggar has always been an adept in evading honest labour, and doubtless those of the seventeenth century were no exception to the rule.

For the first hundred years after the passing of the Act of 1606, it seems to have been the general belief of both masters and men that if a deserting collier succeeded in evading pursuit, by going over to England, or keeping in hiding elsewhere, for a year and a day, he was then at liberty to work where he chose. This was deemed a grievance by the coal-owners, and they sought to have an Act passed in the year 1700 making their title effectual and not subject to lapse if they, within a year and a day of desertion, cited the fugitive at the market cross of the chief burgh of the shire in which he had his residence. The Act was not passed, for what reason does not clearly appear, but decisions of the Court of Session in 1708 and later had the effect of giving the masters what they desired in this particular.

The scope of the Acts as interpreted by the courts may best be understood by reference to some of the cases of which reports have been preserved. A study of the decisions reveals differences amounting to apparent inconsistencies, not only with one another, but with the Acts; and one is almost constrained to think that when a case presented any element of doubt it was not the collier who got the benefit of it.

In the year 1708, Sir Thomas Wallace of Craigie sued William Cunningham of Brownhill for seducing eight or nine of his colliers that were born on his property, and had wrought in his coal-works some years before. Brownhill refused to give them up on the ground that, although belonging to Sir Thomas originally, they had not worked with him for seven or eight years past; and that his having opened a new coal-work was no good warrant for reclaiming, since they had been more than a year and a day away. It appears from the evidence that they had not been a year with Brownhill. The Lords of Session found that colliers could not be hired without a testimonial from their former master, and that Sir Thomas, having now a going coal-work, might well reclaim them; and, although away several years from him, they had not been a year with Brownhill, and that he must restore them. A contemporary legal writer, commenting on this case, remarks:—"By this instance, and some others that have occurred this session, it appears what latitude judges have in the interpretation of laws, sometimes by an extensive interpretation amplifying them beyond what the words carry, and at other times by a restrictive sense limiting them, from equity and circumstances appended thereto."

A somewhat similar case in 1725 between George Lockhart of Carnwath and the tacksman of a coal-work at Saltcoats in reference to a coal-bearer named Kate Thomson, who had absconded from a coal-work at Dryden, was decided in favour of the former master, Lockhart.

That attachment to a coal-work did not deprive a collier of every right of citizenship is pleasingly illustrated in a case decided in 1747. A number of bound colliers at Rutherglen, having been admitted as burgesses, voted in the election of town councillors. Other burgesses of the town, regarding this as an indignity, sought to have the election, so far as influenced by the votes of these colliers, reduced on the plea that the colliers were incapable of voting, but the court held that they were not debarred from voting.

In 1748, John Gibson of Hillhead sued Andrew Scott of Kirklee for delivery of four colliers detained by him. Although it was proved that they had been over a year away from Gibson's work, Scott was held

bound to restore them, on the ground that they were allowed by Gibson to go to Scott's work while the work of the former was not going. An argument used in the pleading, and which appears to have been of some weight, was that, being away by permission, their desertion only commenced from the time of their being required to return.

A collier named Simpson, attached to a coal-work on the lands of Quarrole, deserted that work and went to John M'Leod's work at Bowhouse. Mr. Dundas afterwards purchased Quarrole, receiving at the same time an assignation of the colliers, including Simpson, whereupon, in 1754, he raised an action against M'Leod for restitution. The collier had been several years in M'Leod's work. Judgment was given to the effect that Dundas had right to the property of the collier, and this apparently on the ground that if the requisition be not made within the year the master does not thereby lose his property in the collier, but may recover him at common law. Lord Kames, in reporting this case, expresses dissatisfaction with the decision, and gives the opinion that if Simpson had originally to leave Quarrole because he could not find employment he was free after the year and day.

James Gray of Dalmarnock gave up a coal-work and allowed his colliers to go where they pleased, but took the precaution to reclaim them every year in order to preserve his right to them if he should set up his colliery again. With his consent, six of the colliers settled at Mr. Bogle's work at Shettleston, and remained, some more, some less, than a year, when they were enticed to a work at Barrachnie, belonging to Mr. Cross. Mr. Bogle claimed those who had been with him over a year; but the Lords found him not entitled to any of them. The report shows that these colliers had not bound themselves to Bogle, but it is not clear whether the decision was on this ground, or because they were still bound to Gray.

A case, apparently inconsistent with the decision in Dundas's case of 1754, and in which also Dundas was pursuer, is reported in 1761. A collier who had left Grange coal-work after being there for over a year, wrought in Dundas's work at Quarrole for about a year and a half, when he returned to Grange. Dundas reclaimed him from Grange works. The court found him entitled to recover, because the collier had been over a year in his possession. The apparent discrepancy between this decision and the other referred to may be accounted for, if the collier in this case had bound himself to Quarrole, but this is not stated in the report.

In 1739, James Scott took a lease of coal at Rutherglen belonging to Robert Spence, and worked the same for 16 years, when he gave up the

lease and opened a work on another estate. Spence took the work into his own hands in 1760, and claimed the colliers that Scott had taken with him to the new work. The court upheld Spence's claim, finding that the colliers were not bound to the tacksman, but to the coal at which they wrought during the currency of the tack.

Two lads, who had been bound with their fathers to a coal-work which became exhausted, took employment in a neighbouring work belonging to Sir James Clark, but without binding themselves. They afterwards left, and Sir James claimed them as his bondmen, but his claim was not allowed upon the footing that a man of full age, whether a freeman or bound, entering into another coal-work without any paction of slavery, his working for whatever time will not make him a bondman, and that the argument concludes *a fortiori* in favour of these lads, who were under age.

Mr. Archibald Hope, proprietor of the coal of Harrylaw, was lessee of the coals of Edmonstone, Monkton, and Woolmet, all belonging to different proprietors: and the question came to trial in 1769 in an action at the instance of some of the colliers bound to these coals, whether they could be compelled to work at a coal different from that to which they were respectively bound; or if, upon the coal being stopped, they were entitled to an attestation of a reasonable cause of removal in terms of the Act. The decision in this case was that, as the proprietor of a coal is entitled to remove his colliers to any coal where he has work for them, the tacksman must be in the same situation. In the report of this case reference was made to a case decided in 1762, in which the Marquis of Lothian was held entitled to remove his colliers from one estate to another belonging to him 2 miles distant, and to a case to the same effect between Mr. Wemyss of Cuttlehill and some of his colliers.

The attestation referred to in Hope's case was probably a testimonial from the court, given to colliers on application when they were entitled to their freedom. This proceeding was not specifically authorized by the Acts of 1606 and 1661, but seems to have been resorted to on account of the unwillingness of coal-owners to give up their claims, even after their right to retain their colliers had lapsed.

The following letter, dated 1760, from the Duke of Hamilton's overseer at Bo'ness colliery to a ship master in Leith, mentions this, and shows also that the power to reclaim could be exercised on sea as well as on land:—"But the material fact is that her son Charles Grant is a native collier of Duke Hamilton's, and is at present on board His Majesty's tender, Capt. Brown commander. As it is contrary to the

laws of this realm to keep any man's bond-servant without a certificate from his master or a testimonial from a judge setting forth the cause of his way-going, if you are acquainted with the Hon. Capt. Falkoner I shall take it as a singular favour if you will take the trouble of letting him know that it will be taken kind by the tutors of His Grace if he would order the boy ashore, as it would save His Grace a good deal of trouble and expense that it may cost in obtaining him in a legal way."

In the year 1778, the proprietors of Elphingstone colliery, Tranent, presented a petition to the Justice of Peace court at Hamilton to grant warrant for the apprehension of three colliers who had absconded from that colliery, and were secretly working in a colliery at Tollcross. Warrant was granted, and they were apprehended and put in prison until the father of one of them became caution for them that they would return to their work, he paying the expenses of the action.

On receiving the necessary testimonial, a collier was at liberty to go where he chose, and he could bind himself to another coal-owner.

The court cases reported do not make clear what constituted a binding paction between coal-masters and colliers. Some of the decisions point to work for a year and a day as constituting the bond, but this was not always the case. The workmen no doubt got every encouragement to enter into a binding agreement, and such was common, the essential element of which was the bestowal of a gift by the master, partaking of the nature of arles in the hiring of a servant. It was customary also for the parents of a child to receive a gift from the master at the birth or baptism of the bairn in token of the child's being bound along with the parents.

Some such compact as this was not unnecessary, because, strictly speaking, the bond of servitude did not pass by birth from father to child. The children of the bound collier were not themselves bound, unless they voluntarily followed their father's occupation. It was, therefore, the interest of the coal-owner to encourage the collier and his wife to bring up their children as colliers and bearers.

The wages paid to the collier usually included a gift, or bounty, as it was called, which was paid either annually or on the usual pay day. In 1693, at a colliery on the Forth, the bounty was 10 merks a year, fully eleven shillings sterling. In the latter part of the following century, the bounty was from one-eighth to one-quarter of the wages, but its payment was dependent on the colliers working regularly.

The following authentic particulars from the history of coal-works in different parts of the country serve to illustrate the working out of the system of servitude. As already indicated, it was usual for proprietors

when letting their coal-works to assign to the tenants the rights they possessed in the colliers and other workers. A lease of a colliery on the Firth of Forth, dated 1661, contains the following clause:—"And also with liberty to the tenants to call, pursue, apprehend, and bring back all such coal-bearers and salters who have run away from the said works, conform to Act of Parliament thereanent."

Attached to a lease of coal and salt-works at Bo'ness, in favour of Mr. Cornwall, of Bonhard, dated 1681, is a list of colliers and bearers delivered to him, conform to the tack of the coal and salt-works. There are 13 coal-hewers, 5 male house bearers, 1 of whom is reckoned a half; 21 female house bearers, 5 of whom are reckoned a half each; 1 male fremd bearer and 10 female fremd bearers, 2 of whom are reckoned a half each; in all 13 coal-hewers and 33 bearers. These, with 1 oncost man, the tenant acknowledges to have received, and undertakes to deliver over, or at the least a like number, at the end of the lease. The fremd bearers were those not belonging to the family of the coal-hewer, and who had been hired from outside to assist him.

In a lease of a colliery near Cambuslang, dated 1760, there were let, not only the coal in the lands, but also "the coal-hewers, coal-bearers, putters, cleeksmen, banksmen, gatesmen, and others bound to the said work, and any others that shall be legally employed and become bound during the currency" of the lease. The tenant is "allowed to employ as many coal-hewers as he pleases, and to have full power over them, to require and claim them from other coal-works, imprison and otherwise punish them according to law, in the same manner as the proprietor could do himself."

A memorandum of the number of workers bound to a colliery in the East of Scotland in 1769 is as follows:—"The number of colliers delivered was 55, absent 10; the number of coal-bearers 102, absent 9; the number of salters 16, absent 10; wrights 2; smiths 2; enginemen 8; pitbottom-men 5; banksmen 10; gatesmen, reddsmen, and ginnies 8; oversmen 3; in whole 236, besides children innumerable—472 souls at the common computation."

The mode of reclaiming colliers who had deserted is set forth in the following extract from a journal of the Duke of Hamilton's colliery overseer, dated 1756:—"Went to Shettleston, where we found George and William Love and James Watchman, Sr. and Jr., whom we required at Robert Bogle, Esq., personally: then went to Lightburn, where we found Archibald Watchman and son, James and John Nisbet, and William and John Mathieson, His Grace's own colliers, whom we required at Mr.

McNair personally, and upon the black of his coal-hill from his manager. From this we went to the Coats coal, where we found James Young, and would have required him from John Farie, but to save us that trouble he promised to be good for him till we sent for him. From this we went to the coal-work of Rutherglen, where we found Archibald Paterson, one of His Grace's colliers, whom we required both on the black of the coal-hill from the manager and from bailie Scott personally at Rutherglen. And from this we proceeded to the Muir-heugh of Glasgow, where we found Andrew Wilson, one of Mr. Calderwood's colliers, and required him upon the black of the coal-hill from the manager, as well as from bailie Leitch, one of the masters personally."

As an illustration of the fact that the collier could not be obliged to go from one estate to another belonging to a different person, a case is reported in the memoranda, dated 1769, of a mining engineer who was overseer of a colliery at Dunmore, and who also supervised a colliery on the Forth belonging to another proprietor. The coal at Dunmore having been worked out, and, men being wanted at the latter colliery, the overseer, with the approval of the proprietor, was desirous to get them transferred; and the memorandum indicates that some degree of *finesse* was requisite in order to effect his purpose. The list of workers he gives as 28 colliers, 23 bearing wives, 17 bearing sons, 29 bearing daughters, 3 windsmen and watermen, and 5 fremd bearers.

Robert Bald, a well-known mining engineer of three-quarters of a century ago, on a visit to Mr. Dunlop of Clyde ironworks in 1820, tells of having seen an old man named Nook, in Mr. Dunlop's service, who had originally been bound to Mr. M'Nair's coal-work of Green, and who said he had been niffered for a pony belonging to Mr. Dunlop. Had Mr. Bald possessed a keener sense of humour he would probably have seen a merry twinkle in the old man's eye as he told his story. Some such exchange, no doubt, took place, but the parties concerned knew that it could not be effected without Nook's own consent, and probably he and his master kept up the story as a relic of old times by way of a joke. At any rate, this was the view of the late James Dunlop of Tollcross on the subject.

A recent writer on political economy makes an estimate of the living capital of this country, as represented by its men, women, and children. It is interesting as a speculative calculation. Here is an item of a similar kind, attached to the valuation of a Lanarkshire colliery in 1771 (under lease and with 23 years of the lease still to run), and no doubt considered very practical at the time. "To the value of

the property of 40 good colliers, with their wives and children, at the rate of £100 a-head were they immediately delivered, but as that cannot be for the space of 23 years, their present value at that rate is only £1,302 5s. 7d."

Even assuming that bound colliers were as fairly treated as if they had been free to serve whom they chose, the system was repugnant to the Scottish sentiment, and could not survive the industrial quickening that the country underwent consequent on the development of the use of steam. An Emancipation Act was passed in 1774, the preamble of which runs thus:—"Whereas by the statute law of Scotland as explained by the judges of the courts of law there, many colliers and coal-bearers and salters are in a state of slavery and bondage, bound to the collieries and salt-works where they work for life, transferable with the collieries and salt-works," etc. The Act imposed so many conditions to be observed by those to be freed that little advantage was taken of it. Moreover, many of the masters were not disposed to give up their old rights without a struggle, and they sought to retain their hold on the workers by advancing money on bills which the colliers were too ready to accept, with no expectation on either side of repayment being made, the advances being kept up as debts against them. But the system was hastening to its overthrow, and an Act was passed in 1799 sweeping it away. The bill as first drafted retained some shreds of the old bonds; but the miners, especially those of the West of Scotland, had now awakened up to a sense of their responsibilities. The colliers of Lanarkshire resolved on resistance, collected a subscription of 2s. per man from 600 of their number, sent deputations to collieries in other districts of Scotland, and employed Mr. Wilson, of Cowglen, a law-agent in Glasgow, to conduct the opposition to the bill, with the result that the objectionable clauses were removed.

And thus it came about that the nineteenth century had dawned before it could be said in truth of Scotland, in the words of Cowper:—

> There are no slaves at home: then why abroad?

The CHAIRMAN said that Mr. Barrowman's interesting paper showed very strongly the great progress which had been made with regard to the liberty of the subject during the last 150 years, at any rate in Scotland. In England also, the conditions were very different from what they had been, immense progress having been made not only in the management of mines, but in the liberty of the men and their conditions of life.

Mr. G. A. MITCHELL (Glasgow) said that Mr. Barrowman's paper was an interesting historical account of the past. He thought it would be a matter of surprise to most of the members that such a state of things could have existed within the last 100 years. As far as he knew, that state of matters had been confined to Scotland, and there was no parallel to it in England. He thought that the paper was interesting not only from an antiquarian point of view, but also from a progressive point of view; that perhaps the best way of knowing how we stood at the present moment was to compare the practical conditions with those that had existed. He wondered what would happen if men of those former days could be present at a miners' delegate meeting of the present day. If the man who had been "niffered for a pony" could hear discussions as to what pits were to be thrown idle, and how many days were to be worked, he fancied that man would be rather surprised. Mr. Barrowman's figures as a comparison with the present conditions were specially interesting, and from two points of view. First of all they found only some 55 colliers employed in what they might regard as a typical colliery of the time, possibly a colliery of some size as things were then. It showed them what a great difference there was when they compared these figures with the large number that were employed at the present time, even in the comparatively small collieries of Scotland. Then there was another point: in three or four cases Mr. Barrowman had given the proportions in the numbers of colliers to bearers employed at that early period. In one instance, they had 55 colliers to 102 bearers. Now, if they compared that mine with the conditions in mines at the present time, it showed the extraordinary advance which had been made in the scientific working of collieries. The proportion would be completely reversed.

In connexion with this paper, though hardly relating to the subject directly, but as a matter of interest, the special legislation in Scotland with reference to coal-mines was somewhat peculiar in other respects than those that regarded slavery. For instance, in 1661, an Act was passed which exempted all coal-rents from taxation. Now, that also was a great contrast to the present day, because the principal object of the legislature nowadays seemed to be to see how much of the taxation of the country could be placed on coal-mines.

Mr. J. B. ATKINSON (H.M. Inspector of Mines, Glasgow) said that at collieries in the counties of Durham and Northumberland the yearly bond (which was often declared by the miners' leaders to be a remnant of slavery) was only abolished about 30 years ago.

Prof. HENRY LOUIS (Newcastle-upon-Tyne) enquired whether the Act of 1606 was a new departure at the time, or was merely a codification of the practice then existing. As far as one could trust mining records, in Roman times, mines were worked by slave-labour. In England, they had such records as Queen Elizabeth obtaining a party of German miners to work mines in Derbyshire, and similar records seemed to show that mine-owners pretty continuously owned the miners who were working under them.

Mr. JOHN WHITELAW (Edinburgh) said that the able paper read by Mr. Barrowman had fully proved its title, and shown how slavery came to be legalized in Scotland. It had been his privilege to peruse when at Prestongrange colliery a record, in manuscript, containing reports regarding the development of the workings and the discoveries of new coal-seams, and the modes adopted generally in the conduct of the colliery. In it were recorded inventories of the names of the colliers and their families as belonging to the estate, all carefully enumerated, and of so many as having been lent to the Duke of Buccleuch and the Duke of Argyll, and stating when they were to be returned. From this record, it appeared that the law at that time permitted miners to be borrowed and lent as common chattels. The record to which he had alluded was that of Lord Prestongrange, then Lord Advocate for Scotland (1745), who, from his high legal position, might be accepted as an authority and as one who was not likely to break the law by lending his colliers and causing them to be returned. It might be mentioned that the "arles" were a pair of shoes, the acceptance of which made the colliers bondmen. The Prestongrange colliery was, he believed, the oldest one in Scotland, having been worked by the monks of Newbattle. In a water-level driven from low-water mark, the monks had a sluice-dam to keep back the inflow of the tide. This was opened to allow the mine-water, which had accumulated during high tide, to flow away with the ebbing tide.

Mr. BARROWMAN, in replying to the discussion, said that he had not been able to satisfy himself that the system of slavery existed prior to 1606. He thought that the workpeople had been free to come and go as they pleased, but that the necessities of the rapidly-growing coal-trade, and the inducements held out by coal-owners in new places to men to leave established works, had created the agitation which resulted in the passing of the Act of 1606, enabling them to retain their men. On this subject, Mr. Cosmo Innes writes:—"Last of all, let me mention that

great, peaceful, silent revolution which has never found its way into the pages of our historians. The servile labour of the agricultural class, which had prevailed all over Europe, died out first in Scotland. The last claim of *nefyship*, or serfdom, proved in a Scotch court was in 1364. In that or the following century the institution must have died out."*

The CHAIRMAN moved a vote of thanks to Mr. Barrowman, which was cordially approved.

Mr. Fred. J. Rowan's paper on "A One-rail or Trestle System of Light Railway" was taken as read :—

* *Scotch Legal Antiquities*, page 159.

A ONE-RAIL OR TRESTLE SYSTEM OF LIGHT RAILWAY.

By FRED. J. ROWAN, Assoc. M. Inst. C.E.

Although Britain is the natural home of railways, it is only within very recent times that restrictions have been removed which have in this country presented a barrier to a full development of the usefulness of the system, or even to the same measure of application of it which is found elsewhere. The tendency of engineers in this country has been, and generally is too much, to adhere to a beaten track and to yield little sympathy to departures from it. Consequently, the introduction of light railways, or railways of other forms than the stereotyped one for ordinary traffic, has become commercially possible only within a year or so. It has been possible in the past to construct other forms for private use or for special work, but only under great difficulties as to obtaining permission to traverse land, and without permission to carry passengers except by means of the expensive and cumbrous apparatus of a special Act of Parliament. Moreover, many a project for the construction of a track and vehicles of a novel design has been frustrated because the design was referred to the opinion of a standard railway-engineer, whose adverse decision was a foregone conclusion.

The railway system of the country having grown out of the improvement of means for the transport of coal in large quantities, it is not to be wondered at that suitability for the movement of heavy loads should have been a prime requisite in railway-construction. And the plan of driving by means of the adhesion due to gravity of smooth wheels on smooth rails has still further accentuated that feature as the essential element in the design of railroads. We may indulge in a little imagination as to what might have been the present result if engineers had adopted at an early date some mechanical method of driving-grip less cumbersome and costly than that of the cog-wheels and rack-rail proposed by Mr. Blenkinsop in 1812, instead of the present method. We have to remember also the British prejudice in favour of "something substantial," to which Mr. Mackay in his book on *Light Railways* ascribes the absence of favour towards light railways in this country whilst they have already been largely developed in other parts of Europe.

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* Mr. R. L. Galloway, page 214.

principle it is not new, nor does he propose it now for the first time, as he advocated the system as long ago as 1877, in a paper read before the Society of Arts, in London,* and different forms of the same main plan had previously been patented by Mr. Palmer in 1821, Mr. Etienne in 1846, Mr. Sadler in 1847, Mr. Westley in 1854, Mr. Fell in 1868 and 1869, and Mr. Humphrys in 1870: those of Messrs. Palmer and Fell having the closest resemblance to the special arrangement then proposed by the writer, of which the present plans are a development.

The main idea common to all these plans is that of a "post-and-rail" system of construction; but some engineers have proposed this arrangement in combination with features which cancel the advantages which it possesses, and resolve it into what is virtually an unstable method of carrying or supporting a narrow-gauge railroad.

In order fully to reap the advantages of this system of construction, weight as an element in the driving of the locomotive or vehicles must be as far as possible abolished, and thus some other means of driving than by vertical adhesion must be provided. Some very interesting modern developments of Mr. Blenkinsop's rack-rail are to be found in railways on steep inclines in Switzerland, Germany, Spain, Austria, America, and one or two other countries, whilst driving by means of a combination of rack and adhesion is also to be found: both plans being of course applicable only to tracks with rails for four-wheeled vehicles.

The writer's form of railway, in which a single rail is carried on the apex of triangular trestles or figure of A supports, lends itself readily to the employment of horizontal gripping-wheels by which the amount of grip can be controlled mechanically and independently of the heaviness or lightness of the locomotive. A central rail for horizontal gripping-wheels has been used in several examples of narrow-gauge lines on the Fell system, which is a narrow-gauge with an additional central rail. Even under such circumstances, where extra cost and complication of the locomotive are involved, the horizontal grip being used along with vertical adhesion as an auxiliary for mounting inclines, it has worked well. There can be no question as to the feasibility of driving by horizontal grip, which is for some reasons preferable for light railways to any system of rack-rail driving. In saying this, the writer does not refer to mountain railways for passengers only, in which it has been well proved that the rack is both useful and reliable. Interesting accounts of the equipment and working of several of such railways, and of some having the Fell system, will be found in the *Minutes of Proceedings of the Institution of*

* *Journal of the Society of Arts*, 1877, vol. xxv., page 462.

*Civil Engineers.** But in systems having what may be called auxiliary methods of driving, there is the necessity for weight and bulk in the locomotive which, as an important point, we seek to avoid. The rack-rail and the auxiliary central rail are introduced in order to give means for additional gripping power when the grip due to vertical adhesion fails from the effect due to gravity approaching a vanishing-point. The gravity effect, of course, diminishes proportionately as the angle of the gradient rises from the horizontal. Long before a vertical position can be reached, the weight of the train counterbalances the adhesive effect due to gravity, and the train cannot be propelled up the incline by grip due to vertical adhesion. For instance, the writer finds it stated† that a small narrow-gauge locomotive weighing 18 cwts. could not take more than its own weight up an incline of 1 in 20, although on the level it could draw carriages containing 80 passengers at a speed of 12 miles an hour. Hence the introduction of auxiliary devices which can be used where for a short time speed is not of great importance. In the case of light railways, no provision need be made for anything but a moderate speed—say 15 to 20 miles an hour—and, therefore, we have a freer hand in the selection of the method of grip. It is, of course, evident that horizontal gripping or driving-wheels, such as the writer proposes entirely to rely upon, cannot be made of nearly such dimensions as are employed for vertical driving-wheels, and that, therefore, such wheels would be unsuited for high speeds. But their advantage consists in their giving a greater degree of adhesion than can be obtained from gravity on stiff inclines, and even on a level road enabling a much lighter locomotive to be used. In his case, a steam locomotive weighing, without tender, 6 tons can take 20 tons of train weight up an incline of 1 in 10 at a speed of 10 miles an hour. An electric locomotive to do the same work on this system will weigh considerably less.

Some engineers entertain a prejudice against this form of railway, on account of the mistaken idea that because the vehicles are supported at a small distance above the ground, therefore the railway must be unstable. It is, however, the fact that the centre of gravity of the vehicles is proportionately much lower than is possible in the case of ordinary railway rolling-stock, and therefore the tendency to oscillate or overturn is greatly reduced. In ordinary railway-vehicles, the centre of gravity is a considerable distance above the surface of the rails on which the vehicles run, and we have heavy vehicles on a comparatively narrow wheel-base,

* Vols. xcvi. and cxx.

† *Journal of the Society of Arts*, 1879, vol. xxvii., page 488.

going at a high rate of speed. For smooth running on a straight ro the four wheels require to have accurately the same diameter, and t two axles must be exactly parallel, whilst for rounding curves other c ditions are required. In the one-rail plan, however, the centre of grav is below the rail-surface, there is only one plane in question, and theref the vehicles run more steadily on a one-wheel track than even a bicy does. The carriages are light, and there are guides to prevent a chance oscillation. There is, however, little likelihood of oscillation soon as the vehicles are running. It was found, for instance, even in t old Lisbon tramway, which had a central rail placed on the ground, that soon as the cars attained a fair speed they ran steadily on the cent wheel, rarely touching the guide rails with the guide-wheels, which w placed on each side of the cars. In this case, the centre of gravity w necessarily placed at a good height above the running surface of the ra The same rule holds good in the case of bicycles, where the centre gravity is much above the ground, for these are quite steady when ru ning. In our case, the tendency to oscillate is much less than in thes whilst retaining the advantages of a single track.

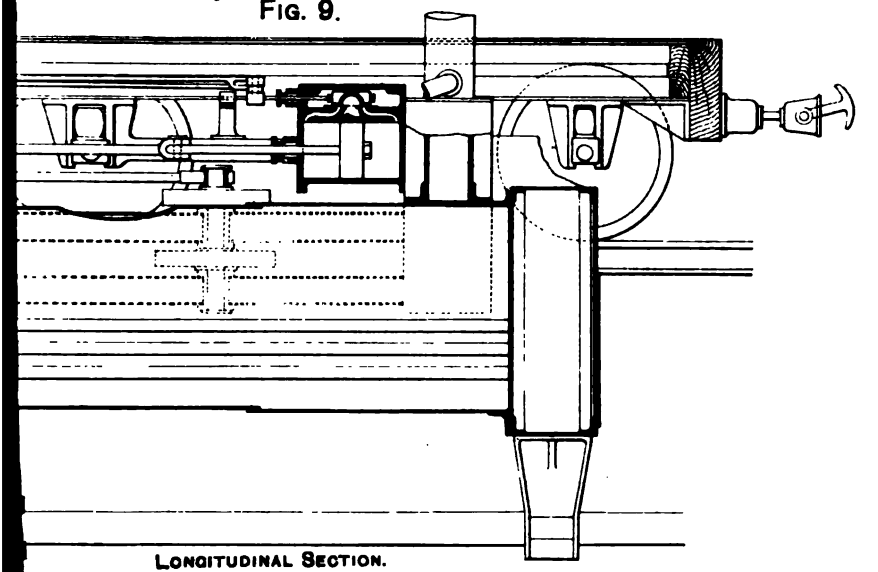
The permanent way itself, on this system, is of a stable form, an with proper bracing of the standards, it would be practically impossibl to overturn, or even to twist the road to any appreciable extent. On great advantage of such a line is that it is easily and quickly laid, and can be, if necessary, removed from one part of a country and utilized in another. This change might become necessary when traffic wa developed, justifying the construction of a heavy track for large vehicles.

As the writer has mentioned electric locomotives, he may add that the form of the railway renders it specially suitable for electrical working.

In carrying minerals from mines, this form of railway offers some advantages. It is cheap and can be used in mountainous regions in which mines are often found, and as the trucks can be emptied downwards, the railway may be elevated over carts or waggons so that the minerals can be discharged into them from the trucks without hand labour. In tropical countries, such a railway offers but little resistance to sudden accumulations of water from heavy rains, which sometimes interfere seriously with the safety of embankments. It follows also, that the entire absence of earthworks and cuttings or tunnels ensures for this system the absolute minimum of unproductive outlay in construction.

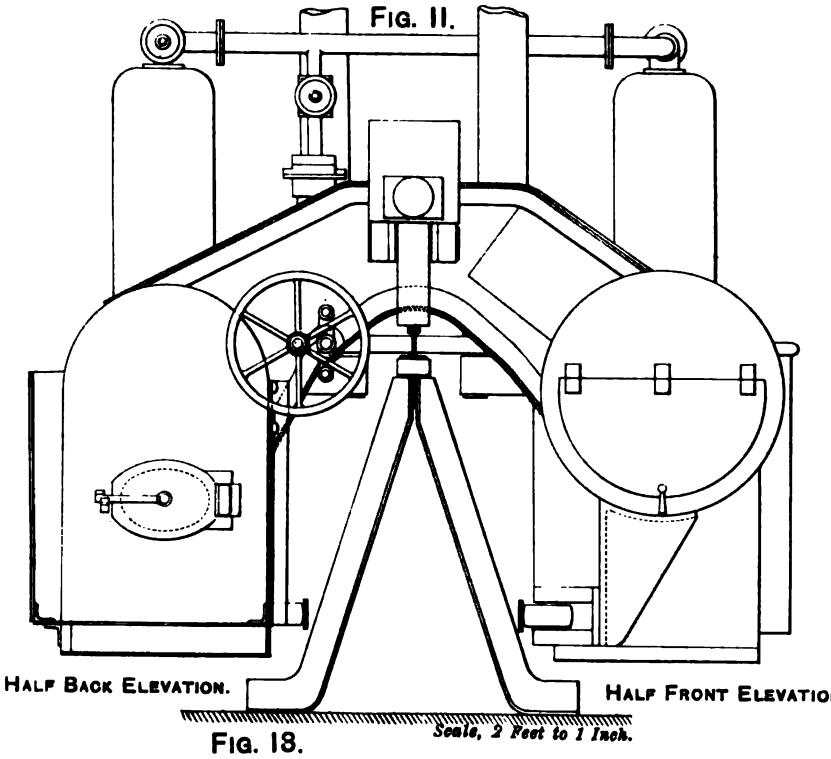
Where the land is valuable, such a system offers the least possible interference with the surface, and the railway merely forms a large fence which may be made high enough to allow of the passage of cattle underneath in grazing-lands or cattle-ranches.

FIG. 9.



LONGITUDINAL SECTION.

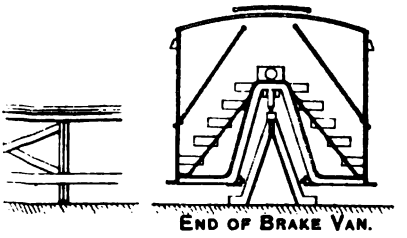
FIG. 11.



HALF BACK ELEVATION. HALF FRONT ELEVATION.

Scale, 2 Feet to 1 Inch.

FIG. 18.



END OF BRAKE VAN.

In the illustrations, Figs. 1, 2, and 3 (Plate XI.) show the general construction of the permanent way; Fig. 1 being a side elevation, Fig. 2 a cross section at one of the supports, and Fig. 3 a plan. The trestles or supports may be constructed of pieces of T-iron bolted together, or of double-headed rails bent to the required form, a longitudinal beam of timber or of iron being laid under the single running rail. The strips or bars forming the longitudinal ties or braces at or near the foot of the supports are used also as surfaces for the guide-wheels or rollers of the vehicles to touch if necessary.

Figs. 4, 5, and 6 (Plate XI.) illustrate the construction of open and close-bodied waggons and carriages, Fig. 4 being a side elevation of an open-bodied waggon, Fig. 5 a cross section, one-half of which shows an open-bodied waggon and the other a close-bodied waggon or a carriage-framing; and Fig. 6 a plan partly in section of these two vehicles.

Figs. 7 and 8 (Plate XI.) illustrate a method of utilizing these small waggons for the transport of large articles or pieces of machinery, such as a 20 feet Cornish boiler.

Figs. 9, 10, and 11 (Plate XI.) are a longitudinal section, a cross section, and a half back and front elevation of a steam locomotive for this railway; and Fig. 12 (Plate XI.) gives a general view of a train of vehicles with locomotive, waggons, carriage, and brake-van, and Fig. 13 (Plate XI.) is an end view of brake-van.

It will be understood that these forms of line and vehicles may be greatly varied; the whole structure of the permanent way, except, of course, the running rail, may, for instance, be made of timber, and waggons may be constructed of basket or wicker-work for conveyance of grain in bulk. Two-storied cars for the conveyance of troops can also be made, approaching in design to the Irish outside or jaunting car, and where the curves are not difficult, the ordinary waggons and carriages may be made of greater length by introducing the use of bogies.

Since the year 1877, there have been several lines of a somewhat similar design constructed. For various reasons, the writer was not interested in their construction, although he had taken some part in making the system known. One of these lines was erected in Algeria by Mr. Lartigue, a French engineer, and more recently a line was constructed in Ireland. One or two specimen lines of saddle-back railway were carried out in America, and it has been proposed to construct the Continental lightning express on a plan having some resemblance to this one, but with vertical driving.*

* Since the paper was written, the construction of the Behr lightning express has become an accomplished fact, and is being shown at the Brussels Exhibition.

Mr. Ernest Benedict (M. Inst. C.E., London) wrote that Mr. Rowan made many assertions, some of which were correct while others could hardly be termed so. While welcoming any contribution to the interesting subject of light railways, the writer fears that Mr. Rowan's scheme, which he has so long advocated, stands but little chance of being put to a practical test. Perhaps his opinion is due to his having a "tendency . . . to adhere to a beaten track" until sufficient reason had been shown for leaving its easy-going for rougher ground; but it was difficult to "yield . . sympathy to departures from it" when no estimate of the cost of so doing was given. "Many a project for the construction of a track and vehicles of a novel design had been frustrated because the design was referred to the opinion of a standard railway-engineer, whose adverse decision was a foregone conclusion," says Mr. Rowan. The writer is a standard railway engineer; he has constructed railways of standard gauges ranging from 2 to 7 feet in width, and would certainly prefer any of these to any new system, more especially if what was new in it was not good and what was good in it was not new, as is unfortuuately too often the case. He (Mr. Benedict) was not prejudiced in favour of present systems. He had advocated a certain form of plate to be run on with flangeless wheels for town tramways, wire-rope telpherage for hill-stations in India, the Brewer system for crossing rivers, and the Behr modification of the Lartigue mono-rail for developing new lands. There is room for them all, and no doubt in certain cases Mr. Rowan's system might be peculiarly suitable if it can be laid down at a reasonable price and be worked at a reasonable cost. Mr. Rowan appears to make it a great point that his trains will run very steadily because their centre of gravity is low. This is an old-fashioned idea; indeed, he himself instances the bicycle as running steadily for the opposite reason. The danger of overturning by reason of a high centre of gravity has been much overrated. Where trains have been upset by the wind, which is the only force likely to cause them to turn over, as long as sufficient superelevation is given and maintained on curves, they have first been lifted and blown off the track, the wind has then got under them and has then laid them gently on their sides. It is seldom that any lives are lost in the process, unless the accident happens on a bridge, for the whole business is a gradual one and necessarily takes place when the train is at rest. A low centre of gravity would not prevent the occurrence, which is, besides, a very rare one. Judging from Mr. Rowan's last paragraph, he has evidently not read the writer's description of the Lartigue system in the *Indian Engineer*,* nor the articles that have lately appeared in *Engineering*,

* June 2nd, 1894.

besides other notices of Mr. F. B. Behr's open lines and projects for future ones. He will, no doubt, be surprised to hear that Mr. Behr's lightning express at the Brussels exhibition is reported to be going on very well, and that Mr. Lartigue is not dead yet.

Mr. THOS. H. MOTTRAM (Glasgow) wrote that the paper read by Mr. Rowan was of a very interesting kind.

The comparatively new one-rail light railway system had much to recommend it, if the advantages claimed could be derived from its adoption. He understood that the primary object was the carriage of light loads, though Mr. Rowan suggests a heavier track for larger vehicles which meant that the system need not be confined altogether to light loads. It was proposed to rely entirely upon horizontal gripping, one of the reasons being that as an auxiliary for mounting inclines it had done good service. He gathered too, that, in carrying minerals from mines, the one-rail system offered some advantages, and he thought that in some cases this might be so, although in competition with the present systems of haulage from and to mines in Scotland, the one-rail system would not, in his opinion, make much headway. There were instances, however, where such a system might probably be used to profit, such as outlying places where the heavy cost of other systems of railways debar communication other than by horse-haulage, and where, consequently, a perpetual additional charge was thrown upon the working of the mineral. One of the principal features which struck him (Mr. Mottram) as being favourable to the system advocated by Mr. Rowan was that the supports for carrying the tressles required but little land, and while this, of course, would not obviate wayleave in some cases, it would render occupancy unnecessary to a great extent, and prevent surface-damages which in some instances amounted to a considerable sum annually.

Mr. F. J. ROWAN, in replying to the discussion, wrote that any fears which he might have entertained from his opening sentences, that in Mr. Benedict he had an uncompromising opponent, were quickly dispelled by his subsequent frank admission, that "in certain cases Mr. Rowan's system might be peculiarly suitable" if laid down and worked at a reasonable cost. As that is exactly his own conviction, he supposes that Mr. Benedict's previous remarks may be taken as expressing merely his dissatisfaction at no figures of cost having been given in the paper. Mr. Benedict is, however, too well experienced an engineer to be guilty of giving away figures without any specification, and, moreover, is no doubt quite able to preceive that for a given weight to be hauled, Mr. Rowan's system of mono-rail construction and working must cost less than any other in which weight is necessary for tractive force. This

statement is to be taken as, of course, excluding cases in which large weights have to be transported at maximum speed. Mr. Benedict is mistaken in the idea that he (Mr. Rowan) had advocated this system for twenty years unsuccessfully. He took an active part in introducing it into public notice, in connexion with the late Mr. J. L. Haddan, in 1877 and 1878; but circumstances, into which it is unnecessary to enter here, compelled him to abandon it entirely for other work until within the last year, when he took it up afresh. He had abundance of evidence, during the former years, that there were many opportunities for the application of such a system if carried out in a sensible and practical manner, and before long he may be able to publish costs of construction and working from actual examples, which are, of course, more satisfactory than estimates. His (Mr. Rowan's) remarks on the influence of a low centre of gravity, in the case of this railway, were really called forth by the strictures of an eminent railway engineer, who objected to this system, on the score of want of stability, because of its elevation above the surface of the ground. He (Mr. Rowan) maintained that on that very point he has a distinct advantage over ordinary railway systems, and the more so the narrower the gauge. The Tay Bridge accident is surely proof that overturning of trains by wind pressure does sometimes happen when the train is not at rest. The instances of the old Lisbon tramway, and of bicycles, merely prove that running on a single rail conduces to steadiness, even with a high centre of gravity. But motion is necessary in these cases, as the vehicles topple over when at rest. In his (Mr. Rowan's) case, the advantages of a single rail, or a bicycle track, are combined with a low centre of gravity, so that he occupies a very stable position. Referring to Mr. Benedict's closing sentences, he (Mr. Rowan) remarked that his paper was written too soon for him to allude to the articles, which Mr. Benedict mentions, as they appeared subsequently. He (Mr. Rowan), had received a copy of Mr. Behr's pamphlet, illustrating his project for the lightning express, but did not then know when it was to be completed. The *Indian Engineer*, containing Mr. Benedict's articles, he had not yet seen, but the reading of them will be a pleasure to come, and, meanwhile, he is indebted to Mr. Benedict for pointing out that he had been misinformed as to Mr. Lartigue's demise. He was glad to find that Mr. Mottram expressed himself as favourable to the system.

The CHAIRMAN moved a vote of thanks to Mr. Rowan for his paper, and it was cordially approved.

Mr. Edward Halse's "Observations on some Gold-bearing Veins of the Coolgardie, Yilgarn, and Murchison Gold-fields, Western Australia," was taken as read :—

OBSERVATIONS ON SOME GOLD-BEARING VEINS OF THE COOLGARDIE, YILGARN, AND MURCHISON GOLD-FIELDS, WESTERN AUSTRALIA.

By EDWARD HALSE.

Nature of Country and General Trend of Reefs.—The general trend of the more important reefs and so-called "reef-formations" is generally north-west to south-east, or they are more or less parallel with the bands of Palæozoic and Archæan rocks marked on Fig. 1 (Plate XII.), reduced from Mr. Göczel's geological sketch-map of the interior gold-region.

At Kalgoorlie (Hannan's), this general trend is particularly noticeable.

The principal gold-bearing band of rocks (diorite and dioritic schist*) in this district is about 8 miles in length by some 2 miles in breadth. The axis of this band, passing in the neighbourhood of the Brown Hill mine, is directed about north 30° west to south 30° east.†

The principal reefs form very acute angles with this axis. Thus the general bearing of the Great Boulder lode is about north 36° west to south 36° east. The Lake View lode to the west and the Ivanhoe lodes to the east of it run in a similar direction. At the Kalgurli mine, the direction is north 38° west, while at the Brown Hill mine it is north 41° west. It would be easy to multiply examples, but the fact remains that there is a remarkable parallelism among the principal lodes of the district.

Cross-lodes running in a general north-east to south-west or east to west direction also occur. They are probably of later age, and, as a rule, are of comparatively small size; they cannot be traced for great distances, and they would appear to be gold-bearing only in the vicinity of the main lodes.

* Mr. W. W. Watts, F.G.S., the well-known petrologist of H.M. Geological Survey, has kindly examined with the microscope some specimens of Kalgoorlie "country" belonging to the writer. A hard greenstone (specimen No. 7), occurring south of the Great Boulder Main Reef mine, he pronounces to be a quartz-diorite with (?) two felspars, green altered hornblende, quartz, and micropegmatite. Other specimens, examined by him, are referred to below.

† All directions are magnetic, 1896-97. The variation in Coolgardie itself for the above period was from 1 to 1½ degrees westerly.

It is remarkable that the chief producing mines at present, viz., Great Boulder Proprietary, Lake View Consols, Ivanhoe, Brown Hill, Great Boulder Main Reef, and North Boulder, are comprised within an area of ground 1½ miles in length (north-west to south-east) by 1 mile in width.

At Menzies, the direction of the principal reefs is very nearly north-west to south-east, but it should be noted that the reefs here are thin in comparison with the wide lodes of Kalgoorlie, and they appear to pursue a more undulating course, ranging from about north 30° west to north 50° west.

Among the mines in the district which have returned a fair amount of gold may be mentioned the Menzies Crusoe, Menzies Gold Reefs Proprietary, Lady Shenton, and Queensland Menzies.

One reef-formation, 3 feet in width, about a mile south-east of the township, strikes from north 35° west to north 40° west, dipping south-west from 54 to 68 degrees. It consists apparently of altered schistose diorite with veinlets or "leaders" of quartz and limonite. The hanging-wall appears to consist of diorite in layers parallel to those of the "formation."

At Southern Cross (Yilgarn gold-field), the principal reefs have also a general north-west to south-east trend.

Thus at Fraser's, the general strike is north 38° west; again, a little west of the main line of reefs, the direction is north 37° west.

Here the reefs appear to be of uniformly low grade value. The three principal mines—Fraser's, Fraser's South, and Central—had, up to the end of last year, crushed 135,152 tons of quartz, which yielded 77,271 ounces of gold, or an average of 11·4 dwts. to the ton.*

At Day Dawn (Murchison gold-field), the direction of the big reef (from 9 to 24 feet in width) of the Consolidated Murchison mines is about north 38° west, the dip being south-west 65 degrees. This is again a low-grade reef, as the free-milling value of the ore averages about 12 dwts. per ton. Previous to 1896, however, the average was a little over 13 dwts., while it had dropped to a little under 10 dwts. in 1896.

The smaller (2½ feet) Day Dawn west reef on the same property runs about north 50° east. The average milling value of the ore from this reef is about 15 dwts.

* *Gold Mining Statistics for the Year* 1896. Table No. 2 compiled by Mr. Frank Reed, departmental engineer and statist. Department of Mines, Perth, Western Australia.

At Kunannalling (Twenty-five Mile), a north-west to south-east direction is also noticeable, but some distance north and north-west of the township the direction is north-north-west to south-south-east. Here, as at Coolgardie, we are on or near the contact-zone between the gneiss-granite formation from the west, and the Palæozoic greenstones from the east.*

At Kurawa (Broad Arrow), the prevalent direction near the township is about north-north-west to south-south-east. This is the direction of the Hill End reef, which is famous for having returned, during 1896, 6,708 ounces of gold from 509 tons of stone crushed. The Pride of the Arrow, adjoining it, runs north 20° west.

The next most prevalent directions in the gold-fields appear to be north to south and north-east to south-west.

In the Coolgardie district, a glance at the Government map of the leases shows that from 2 to 4 miles south of the town the latter direction prevails, while to the south, east, and north the direction of the principal reefs nearly corresponds with magnetic north and south.

The fact is that, in Coolgardie, the principal reefs run parallel to the contact-line (trending north and south) between the amphibolites and other schistose rocks on the east and the gneissic-granite† on the west.

The reefs of this district have the reputation of being very irregular in gold-contents, and the developments have undoubtedly proved this to be the case in many instances. There would appear, however, to be several exceptions to the general rule. Among the mines which have produced most of the gold may be mentioned Burbanks Birthday Gift, Lady Loch, and Bayley's United; while among the mines usually considered of great promise may be mentioned the Empress of Coolgardie, Tindall's, the Australasian, and the Vale of Coolgardie. (The last is situated at Bonnie Vale, a few miles north of the township.)

Cross reefs, consisting principally of "dig" (*i.e.*, crushed and resolidified country) with mispickel in the upper levels and iron pyrites in the lower levels, throw the main north to south reefs, and are therefore of later origin. These cross reefs are sometimes filled with ironstone and sometimes with quartz, and are auriferous in many instances.‡

* Mr. S. Göczel, *Ad Interim Report of the Department of Mines*, 1894, page 22.

† A specimen (No. 3) of the granite from the township of Coolgardie is pronounced by Mr. Watts to be "strictly speaking a granitite with two felspars, quartz, brown mica, and iron ores."

‡ Mr. S. Göczel, *Ad Interim Report*, 1894, page 19.

At Kanowna (White Feather), the prevalent directions of the reefs are north to south and north-east to south-west, and here again is a district noted for the rarity or inconsistency of the gold contents in the reefs.

Among the exceptions, the White Feather Reward and the Robinson may be cited; the former has already returned a considerable quantity of gold.

At Cue (Murchison gold-field), the prevailing directions, again, are north to south and north-east to south-west. Here the reefs occur in granitic "country." They are thin and frequently rich near the surface, but they usually become very low-grade in depth.

Vein Systems.—Besides the north-west to south-east and north to south reefs, and their cross veins running north-east to south-west or east to west respectively, there would appear, in certain districts, to be several systems of veins.

Thus about 8 miles north-east of Dunnsville (Wealth of Nations) there are :—

(1) East-to-west veins of white quartz of variable dip and thickness.

(2) North-to-south veins dipping east, and filled with brown quartz or quartz and "country."

(3) North-west to south-east veins of brownish and amber-coloured quartz, dipping north-east; and

(4) North-east veins of brown and yellow ironstained quartz, dipping south-east at a high angle.

Of the above (1) are probably the oldest, and are non-auriferous; (2) generally occur as rich "leaders," a few inches wide, of quartz and soft "country," which intersect and enrich (3); and (4) run parallel with the main joint-planes in the hard diorite.

Local Strike.—The fact that a variation in strike is frequently followed by a marked variation in the nature and value of the mineral contents has frequently been observed in metalliferous veins in different parts of the world. An example or two from the Coolgardie gold-fields will suffice :—

On one claim on the Great Boulder line (Kalgoorlie), the lode is rich and powerful where the direction is about north 43° west to south 43° east. To the south the lode enters very hard diorite and the strike becomes north 33° west to south 33° east for a considerable distance. Here the lode has shrunk considerably in size, and is characterized by

poverty. It should be noted also that horizontal joints carrying kaolin or white clay cross the lode where it is pinched.

A reef near Bulla Bulling contained a fair amount of gold, when the bearing was from north 8° west to north 10° west. When it changed to a few degrees east of north, the reef became almost sterile.

The "country" here had the appearance of talcose, ironstained "grit," or sandstone; but, according to Mr. Watts,* it comes nearest to the gneissose granulites. Similar "country" occurs south of Kurawa (Broad Arrow) and east of Cuddingwarra, on the Murchison gold-field.

Dip.—It is worthy of note that of the north-west to south-east and north-to-south veins the prevailing dip is to the south-west and west respectively. Exceptions occur, of course, but they are by no means common.

The big lodes of Kalgoorlie, when passing through very hard diorite, are frequently nearly vertical, or appear to oscillate a few degrees to the east or west of the perpendicular. Thus the Great Boulder lode, to the depth of 150 feet, dips steeply to the east, but below that depth the dip is sharp to the west.

The same lode, farther south, frequently shows a change of dip from east to west, or *vice versa*, within a few feet, measured vertically or horizontally; so that the dip is actually a zigzag one.

The cross reefs at Kalgoorlie (general direction north-east to south-west) usually dip north-west, but at a somewhat sharp angle.

In the North Niagara district, one auriferous cross reef trending east-north-east, dipped south 65 degrees.

Associated Minerals.—As a rule, very few minerals are associated with the gold. The gangue is quartz, ironstone, and more or less altered "country," while iron oxides, notably limonite with oxides of manganese occasionally, above water-level, and iron pyrites or marcasite and mispickel below, are usually associated with the free gold.

At Bayley's mine, Coolgardie, below water-level, mispickel crystals, enclosing visible free gold, were not of rare occurrence (Mr. S. Göczel).

In certain districts, the gold is commonly associated with other sulphides. Thus about 8 miles north-east of Dunnsville (Wealth of

* In a letter to the writer, Mr. Watts says:—"I have never seen anything quite like this rock. I do not think that it is a grit or sandstone. The rock comes nearest to some of the gneissose granulites. The minerals are two felspars, quartz, and altered brown mica."—Specimen No. 1.

Nations), in one quartz-vein, at a depth of about 70 feet from the surface, coarse gold is associated with arsenical and copper pyrites, with some bornite, galena, blende, and chlorite.

The reef strikes about north-west to south-east in a hard quartz-diorite, strongly impregnated with iron pyrites.

The vein is very irregular in thickness (from 9 to 30 inches) at short intervals; in other words it frequently swells out and contracts, both horizontally and vertically. The gold also is very irregularly distributed in the vein. At one point, the reef will average several ounces to the ton, while a few feet above or below, it will run only a few pennyweights or be absolutely sterile. Where the reef is poor, the sulphides are very sparsely distributed in the quartz-gangue.

In this mine, a rich north-and-south leader, which forms a junction with it, seems to have determined the distribution of the gold in the reef. Notwithstanding this, a sample taken just above the point of contact gave only traces of gold.

At the surface, the reef crops out as layers of quartz interbedded with schistose diorite, 20 inches in width, and is capped by cement,* or a white agglomeration of angular fragments of quartz, diorite, and syenite cemented by kaolin and stained here and there by oxide of iron. This cement is richly besprinkled with visible gold, both coarse and fine.

Zinc blende in small crystals has been found in some of the north-west to south-east reefs of Mount Burgess.

In one reef, a few miles west of Kurawa (Broad Arrow), striking north-east by east in diorite, the gold is associated with iron, copper, and arsenical pyrites and galena. The gold is found in or around quartz-crystals, and sometimes in siderite.

The occurrence of tellurides in some of the reefs of the Coolgardie gold-field is of great scientific interest, although, perhaps, its importance from an economic point of view has been somewhat exaggerated. Telluride of gold was first identified about May, 1896, in Block 45 mine, about $1\frac{1}{2}$ miles south-east of Kalgoorlie (Hannan's). Since then, it has been discovered in several mines of this and other districts.

* This so-called cement is totally different from the cement of Kanowna (White Feather) and Kunnallaling (Twenty-five Mile), which consists of more or less rounded fragments of quartz, cemented together by a clayey talcose mineral in the former place, and by a kaolin mineral in the latter locality. The deposits are more or less basin-shaped, and are probably of alluvial origin. Mr. Göczel, however, appears to regard them as the result of hydrothermal action.

The tellurides in the Kalgoorlie district occur below the upper zone of surface decomposition, and at depths varying from about 50 to 200 feet. In Block 45 mine, the ore was met with at 100 feet, and at the Kalgurli mine it was first noticed about 70 feet from the surface. At another mine, on the Great Boulder line, tellurides occur about 175 feet down.

The tellurides are sometimes scattered through the reef for a width of several feet; they are sometimes concentrated in a thin band or pay-streak. In one instance the band was from 10 to 12 inches wide at a distance of 3 feet from the foot-wall. The rest of the lode was low-grade.

The filling appeared to be hard diorite, quartzose in places, and impregnated with iron pyrites. No joints or selvages separated the pay-streak from the rest of the filling. Some distance farther north, however, the tellurides were scattered throughout the whole width of the face. They were apt to be irregular in distribution, sometimes cutting out altogether, but coming in again in the next foot or so of drivage. Here and there, the tellurides of gold were associated with free gold and a variety of tetradymite (telluric bismuth), which itself did not appear to contain gold. Some fine examples of this mineral in foliated masses have been met with. It resembles plumbago, but a freshly-cut surface has a peculiar dull red colour, somewhat resembling dark ruby silver.*

The tellurides of gold at this particular mine appear to be of two species or varieties: one silver white in colour (? variety of sylvanite), and another having the colour of mispickel, but which appears bronze-yellow when viewed obliquely (? variety of calaverite).† The former is generally in aggregated masses, while the latter occurs as isolated crystals scattered all through the stone.

The tellurides at Kalgoorlie are usually associated with iron pyrites, the gangue being hard, more or less altered "country."

Specimens (Nos. 4 and 5) of lode-filling containing tellurides from the Kalgurli and Hannan's Star mines, occurring at depths of about 150 and 175 feet respectively from the surface, have been examined microscopically by Mr. W. W. Watts. He says that they "look like crushed

* Tetradymite has also been found by Mr. A. Octavius Watkins at the Dunallan mines, near Coolgardie. It occurs in brilliant silvery-white crystals in white glassy quartz.

	Gold.	Silver.	Tellurium.
† Analysis of calaverite	40·41	2·30	56·58
Do. telluride from Hannan's	36·95	8·36	54·50
Do. do. Block 45 Mine	42·60	0·70	54·10

The last also contains arsenic 1·10, iron 0·90, and sulphur 0·40.—*Mining Journal and Investors' Review*, Perth, Western Australia, April 28th, 1896, page 23.

aplites or granophyres. They contain lumps of quartz and iron ores embedded in a fine schistose matrix of sericite."*

The pyrites sometimes run in lines in the stone, and the free gold is then apt to follow such lines. The writer has detected spots of telluride in what looked like a hard granitic dyke containing iron pyrites in cubes, which in one place formed the hanging-wall of the gold-and-telluride-bearing lode.

Although the dyke dipped sharply north-east, the schistose layers in the "formation" itself dipped south-west 82½ degrees. The contact-line was irregular, the granite sometimes overlapped the schistose formation, and *vice versa;* but for an inch or so next to the contact-line the granite was seen to have a schistose structure. The granite was jointed. One set of joints, dipping south 50 degrees, was crossed by another set nearly perpendicular, or dipping sharply to the north, thus forming blocks.

Mr. Watts, who examined a specimen (No. 6) of this rock with the microscope, says it is a "granophyre or aplite—such a rock as might be a dyke from a granitic mass. Quartz and felspar intergrown together in the common form of micropegmatite are the chief constituents. Pyrites is present."

So-called "mustard gold" occurs in Hannan's Brown Hill mine. Rich patches of similar gold have recently been found in the Great Boulder mine. This gold is in a different allotropic condition from that generally found in reefs, being red, purple, or brown in colour, like precipitated gold. By beating or rubbing in an agate mortar it assumes the usual gold-colour and lustre. Some writers regard it as the result of the decomposition of telluride of gold, and therefore as a forerunner of that ore. However this may be it is probably of much more recent origin than the lode itself.

Colour of the Quartz.—Too much stress is often laid on the colour of the quartz that bears the gold. In Western Australia, gold appears to occur in quartz of various colours. A milk-white opaque quartz, with a glassy lustre, is generally regarded as non-auriferous, and would be termed a "buck quartz" or stone by the "new chum" from the eastern colonies, while a Cornishman would call it "hungry spar."

Such quartz is frequently very rich in coarse gold, and much of the quartz exhibited in jewellers' windows in Bayley Street, Coolgardie, is of

* It is only fair to mention that the sections of Western Australian rocks examined by Mr. Watts for the writer were too coarse, making it therefore difficult to identify the rocks. Other sections are being prepared, and the results will be given in an *addendum* to this paper.

this description. Sometimes gold forms the cementing-material holding angular fragments of such quartz together. Reefs, consisting of this variety of quartz, are notoriously patchy, and the patches, as a rule, are few in number, and long distances apart.

At Kanowna (White Feather), quartz of this character is very common, but what is singular is that this kind of quartz in that district not only contains coarse gold here and there, but it contains a certain amount of fine gold disseminated throughout.

The writer once had occasion to sample a mine near Kanowna in which a good deal of development work had been done. The reefs, from 1 to 3 feet in width, ran nearly north-east to south-west, and dipped sharply to the north-west. They had been proved to a depth of about 150 feet, and for several hundred feet in length. The filling was principally quartz of the character described above—some pockets of the quartz carrying coarse gold had been found at and near the surface. Samples taken from various points in the mine assayed from 3 to 5 dwts. of gold to the ton, and none of the quartz was proved to be absolutely barren.

On another occasion, a reef a few miles south of the township was examined, consisting of the same class of quartz. The strike was nearly east to west, and the dip was south 25 degrees. At the surface, the reef was about 2 feet in width, and in places contained several ounces of coarse gold to the ton. At 45 feet in vertical depth, the reef was from 2 to 18 inches thick, and contained from nothing to a few pennyweights of gold per ton.

Quartz of a grey colour and dull in lustre is very common on these gold-fields, and is frequently more or less gold-bearing.

Grey laminated quartz with chlorite, actinolite, etc., containing very fine gold fairly well disseminated throughout, occurs in places, *e.g.*, at the White Flag (Twenty-one Mile), and also south of Kanowna (White Feather). The reefs, however, are thin.

Quartz of a dark blue colour was formerly regarded as non-auriferous; but quartz of this colour is common in the Mysore district of India, and is also found in Merionethshire, North Wales, and in other parts of the world, and such quartz is frequently gold-bearing.

In the Day Dawn district, on the Murchison gold-field, this class of quartz is common, and is frequently gold-bearing to a surprising extent.

Near Bulla Bulling (Coolgardie gold-field), a mottled stone consisting of blue and grey quartz occurs, which carries fine gold.

Amber-coloured quartz is very common in the Coolgardie and other

districts. At and near the surface, it frequently contains gold disseminated in the solid quartz in the form of spangles; it would almost seem as if the gold had been entrapped by the silica when the latter was in a gelatinous condition. Some curious examples of this occur a few miles north of the town. Unfortunately this kind of quartz does not appear to carry gold to any depth.

On one claim, amber-coloured quartz containing visible free gold was traceable at the surface for a length of about 230 feet. It assayed, on an average, rather more than 1 ounce of gold per ton. A shaft was put down on this reef to a depth of about 40 feet. Unfortunately, at this depth, the gold contents dropped to about 5 dwts. per ton, and became unpayable.

Bedded Veins.—Besides the ordinary quartz-reefs or fissure-veins and the reef-formations, or auriferous igneous dykes, or auriferous metamorphic rock-bands, numerous "bedded veins" occur in different parts of the gold-fields.

In the case of reefs having a banded structure conforming to the layers of the "country" forming the walls, it does not necessarily imply that the reef is a bedded vein. The layers may not be stratification-layers but cleavage-planes produced by lateral pressure applied subsequently to the formation of the reef itself.

The bedded veins often consist of thin layers of quartz having a flat dip—examples of such veins are to be found in various parts of the gold-fields, notably in the Bardoc district, and at Mulline in the Coolgardie gold-fields, and at Cuddingwarra in the Murchison gold-field.

They possess certain features of interest which would require a separate paper for their treatment. It may be stated here that such deposits are apt to be of a pockety nature, often carrying rich patches of gold at and near the surface.

Segregations.—There are some irregular deposits of quartz and ironstone, which can only be classed as segregations. One was found at Yalgoo (Murchison gold-field), and is described as having been "a surface deposit of quartz of boat-like shape, about 100 feet in length by about 10 feet in width and depth," which yielded about 4,000 ounces of gold. "Although a few rich quartz-leaders have (since) been discovered and worked profitably, the rich deposit before referred to occurred in a dioritic schist country, but had no defined walls, and was not enclosed in any description of fissure or lode." *

* Mr. Frank Reed in *Report of Department of Mines for 1895*, page 41.

Ore-shoots.—Most ore-shoots have a definite pitch in one direction of the strike; and in these gold-fields, in reefs striking north-west to south-east, it is more often in the latter direction than in the former.

Sometimes the shoots are practically vertical (and then become ore-columns), or they are more or less horizontal ("course of ore"). In many instances, no definite shoots, courses, or columns are known to exist. Very frequently the gold occurs in spots and bunches, very irregularly distributed in barren or low-grade material.

It may be stated, in general terms, that in the larger and better defined reefs definite shoots of gold are apt to occur, while in the smaller reefs the distribution of the gold frequently appears to be very capricious.

Mr. Göczel says:—"In most of the reefs or lodes within the interior auriferous region the gold occurs chiefly in shoots or ore-columns. The horizontal extents of such shoots along the course of a reef are seldom defined by nature. The most common occurrence is a gradual decrease in richness from the axis of a shoot in both directions along the reef."*

In the Great Boulder mine, the main shoot is 415 feet in length at the 100 feet level. It is well known that this phenomenal lode is split into two branches (locally known as the east and west lodes) by a horse of ground for about 200 feet in length. The split occurs in the richest ground in the mine, and the two branches are equally rich for over 200 feet.

At the 150 feet level, the rich shoot extends on the east branch 205 feet and on the west branch 412 feet. At the 200 feet level, the shoot, by September, 1896, was driven in the east branch 270 feet and in the west branch 75 feet.†

The pitch of the shoots in this mine is to the south-east.‡

At Hannan's Brown Hill mine, the large ore-shoot there—proved for a length of 400 feet, and for a maximum width of from 60 to 120 feet—is said to pitch south-east at an angle of about 40 degrees This singular deposit consists, in the upper levels, of layers of dioritic schist impregnated with oxide of iron, pyrolusite, and free gold, crossed by nearly flat east-and-west leaders. The dip is west, but variable; the thickness is also very variable, and the lode has no defined walls. Where the lode is widest it is in places exceedingly rich, and is stated to be payable right across.

* *Report*, 1894, page 4.

† From a Report by Mr. Joseph Garland, *Mining Journal*, September 26th, 1896, page 1222.

‡ To the end of 1896, 21,020 tons of ore were milled for a return of 82,614 ounces of gold, or an average of nearly 4 ounces of gold per ton.

Coarse nuggety gold occurs in seams on the faces of the greenish schistose "country"; the latter, in the lower levels, changes to hard green slaty rock.

The richest ore appears to be on the foot-wall side. Northward, the lode is much smaller, and only contains a few pennyweights of gold to the ton; and although it is being followed to the south, the claim to the south of the Brown Hill has not yet been fortunate enough to strike payable stone, although considerable development has been done on what is regarded as the extension of the Brown Hill lode.

The deposit would appear to be an enormous bulge, and more in the nature of an irregular deposit than a fissure-vein.

It would seem probable that the filling has been the result of long-continued hydrothermal action.

Some fine examples of "mustard gold" occur in the upper levels of this mine.

At the Kalgurli mine, the pitch of the tellurides is to the south-east.

In the Coolgardie district, the lodes are broken and thrown. "They carry gold in shoots, and almost in every instance the occurrence of gold is connected with such breaks, throws, or faults."*

The General Gordon lode is said to consist of a band of highly altered schists and slates from 20 to 50 feet in width, purple, dark brown, and dark green in colour. The slates contain vughs filled with gossany ironstone and quartz, in irregular-sized lenticular masses resembling green and pink flint. Gold may be traced down the wall of one shaft to within 2 feet of the bottom. It there forms a yellow speckled band that appears to pitch sharply to the south.

At one mine in the White Flag (Twenty-one Mile), a shoot of gold had a length of about 80 feet, and the pitch appeared to be about south-east 30 degrees.

Mr. Göczel speaks of one mine near the Twenty-five Mile having a rich shoot dipping south.†

At one reef in the North Niagara district, running north-and-south and dipping east 45 degrees, the shoot pitches north.

At Nannine (Murchison gold-field), shoots of gold appear to be determined by the intersection of ironstone-bars or diorite-dykes, or by breaks and lines of fracture.‡

At the Nannine mine, a shoot occurs, pitching north 45 degrees,

* Mr. S. Göczel, *Ad Interim Report*, 1894, page 19.

† *Op. cit.*, page 22.

‡ *Report of the Department of Mines for* 1895, Perth, 1896, page 44.

which has been followed down to a depth of about 200 feet. The reef courses north and south in dioritic schist, and dips sharply to the west.

At the Royalist Consolidated mine, immediately south of the above, two main shoots are known. One of these pitches north 80 degrees, and the other pitches in the opposite direction, at about the same angle. This mine has been opened to a depth of 110 feet, and a length of 250 feet.

At the Mainland Consols mine, Lake Austin (Murchison gold-field), the reef runs north-east to south-west, nearly vertically. The hanging-wall consists of a decomposed diorite, and the foot-wall of clay slate and ironstone. In this mine, a rich shoot, carrying very coarse gold, is said to strike diagonally across the reef in a south-westerly direction (? pitches south-west).

In some reefs, as already pointed out, the distribution of the gold is remarkably capricious, and appears to follow no known laws of deposition. It is apt to occur here and there in rich spots, the rest of the filling being low grade or even absolutely sterile. To arrive at an approximate valuation of such reefs it is necessary to mill many hundreds of tons of ore. Too much reliance must not be placed on assay-values of samples, even though taken with the greatest care, and from a number of points in the reef.

Mr. Göczel says, speaking of Cue and Day Dawn, that "the intersection of reefs with cross reefs and cross fissures plays here also an important *rôle* in the occurrence of gold-shoots. The shoots in lodes which have Archæan rocks as country formation have usually a larger horizontal extent within the lode than shoots in lodes within Palæozoic greenstones, although phenomenal richness goes more with the latter class."*

At West Mount Magnet (Murchison gold-field), one north-and-south reef in talcose schist, dipping west 75 degrees, has a rich shoot which pitches to the south.†

As the rich shoot at Bayley's mine, Coolgardie, was long ago worked out the following description of it by Mr. Göczel should prove interesting :—‡

The ore-deposit in Bayley's mine is a quartz-reef from 4 to 8 feet wide, running in a more or less north to south direction ; the reef dips towards east under a steep angle. The country-rock is diorite and amphibolite, greatly decomposed towards the surface ; the hornblende in it is altered to a chloritic mineral substance, and the felspar (plagioclase) kaolinized.

* *Report of the Department of Mines for* 1894, page 33.

† *Op. cit.*, page 42. ‡ *Ad Interim Report*, 1894, page 19.

The quartz-lode in its richest part may be considered as a double lode. The primary quartz-lode was, during later disturbances, transversely broken, and parts of it dislocated. In the part last formed, the rich gold-shoot, a longitudinal break, has reopened the old fissure, the quartz of the primary lode was to some extent broken in fragments, and a new fissure—running sometimes along the walls, sometimes in the middle of the lode—was formed. During the time of the gold emanation (in all probability the time of hydrothermal activity in this part of the earth), this fissure was reclosed by deposition of new quartz, iron pyrites, mispickel, and metallic gold. The mineral solutions have passed, not only the main fissure, but have also entered the spaces between the broken quartz of the primary lode, and their deposits, consisting of the above minerals, have recemented the fragments. As these solutions were rich in gold, the origin of the specimens, in which barren quartz-pieces are held together by metallic gold, is explained.

The younger part of the lode appears in the workings in the form of a band of quartz of different colour and structure. It runs sometimes along the walls, at others inside the primary lode. That quartz is exceedingly rich in gold, and carries the metal as coarse and fine impregnation.

At one mine at Mount Burgess, a 5 feet north-to-south reef, dipping west 45 degrees, is crossed by a 3 feet east-to-west lode dipping north 45 degrees. The east-to-west lode is younger, and is auriferous. Rich stone, carrying coarse and fine gold, is obtained at the point of junction. "Here also the traces of thermal activity are visible, and the almost complete alteration of the amphibolite country-rock into a white friable silicate of alumina and magnesia is due to that action."*

Faults.—The faulting of the north-to-south and north-east to south-west reefs of the Coolgardie district by east-to-west faults or veins has already been noticed.

At Kalgoorlie, the big lodes are not infrequently thrown a few feet by faults or veins striking in a general east-to-west direction.

The Great Boulder main-reef lode (the continuation of the Great Boulder lode to the south of that mine) is several times thrown to the west by cross joints, veins, or "slides" with a flat westerly dip. In one instance the throw was 6 feet, and in another instance as much as 10 feet to the west.

The Chaffers lode, to the west of the above mine, is also several times thrown some feet in a westerly direction by cross joints or courses dipping flatly to the west. The strike of the reef is north 32½ degrees west.

At the White Flag (Twenty-one Mile), a reef, which was from 3 to 4 feet thick near the surface, was at a depth of 60 feet disordered by a slide or clay flucan. The slide for a certain distance dipped sharply to the west. The gold-bearing quartz, about 12 inches thick on an average, sometimes

* *Op. cit.*, page 22.

lay on the slide, and sometimes occurred inside the flucan in bunches. Afterwards the dip of the slide changed to east 28 to 38 degrees, which change of dip appeared to determine the limits of the shoot of gold.

In certain portions of the gold-fields the "country" is very much broken up and faulted. A greatly faulted area occurs a few miles south-west of the Broad Arrow township. Here overlap-faults are not uncommon, and the somewhat flat veins are so frequently broken and thrown up or down that it is extremely difficult to follow them.

The effect of hard quartz-diorite on a small quartz-reef is shown in Fig. 2 (Plate XIII.). The reef, striking north 56° east, and dipping north-west 82 degrees, is composed in the upper levels of a white quartz-leader, 18 to 20 inches thick. In places, there are two leaders from 9 to 12 inches thick separated by "country." Below 74 feet from the surface, the reef enters hard quartz-diorite. Soon after entering, the leader on the hanging-wall side thins away to nothing. That on the foot-wall side does the same, but just about where it commences to thin off another leader begins, and continues down to the bottom of the shaft (103 feet) where, however, it has diminished to 6 inches of grey quartz. This appears to be an interesting case of what is known as "splice" in a vein. Notwithstanding the hard nature of the country, the quartz still contained an appreciable amount of gold (4 dwts. 15 grains per ton).

The general effect of the hard diorite as well as a fault on the reef is shown in Fig. 3 (Plate XIII.). The diorite comes in from the north-east, dipping south-west 24½ degrees, while the fault on the south-western side of the shaft dips south-west 53½ degrees. Practically, everything is cut off by the diorite and fault. The thinning away of the reef at the fault is also remarkable. In one level near the shaft, it is 3 feet wide, but towards the south-west it gradually thins off to 9 inches at the fault.

Replacement.—The so-called reef-formations are by Bergrath Schmeisser termed composite veins, and by another author complex lodes.* Neither of these terms appears to be satisfactory, seeing that they can be applied to most large lodes whose structure is more or less complex.

Mr. Göczel boldly states that the reef-formations or "compound lodes" are simply igneous dykes.† That they were originally so in many instances appears very probable, but certain very wide "formations" consist of what appear to be bands of metamorphic schists and slates.

* Baron Sloet van Oldbruitenborgh, *Mining Journal*, July 10th, 1897, page 819.

† "The compound lodes are simply dykes (sometimes diorite or diabase, but chiefly felsite-porphyry) containing smaller auriferous quartz-lodes in their body." *Ad Interim Report*, 1894, page 29; see also *Report*, 1895, pages 24 and 25.

Reference has already been made to one such deposit known as the General Gordon lode. Others occur close to Coolgardie, beneath what used to be known as Fly Flat, where the "dry blowers" in the early days found "slugs" of alluvial gold.

One such deposit consists of a greatly altered schistose band about 20 feet in thickness, with thin leaders and stringers of quartz and iron oxides running irregularly along and sometimes across it. The leaders are not continuous, but come in and go out at short intervals. Here and there, small bunches and layers of quartz are visible. Kaolin is common in the lode, and sometimes the filling consists of black clay resembling "douk."

The deposit strikes north-north-east to south-south-west, and dips east-south-east 75 degrees. The "country" on the hanging-side appears to consist of diorite, and that on the foot-wall side of schist. The walls themselves are seldom defined, especially the foot-wall. In one place, the hanging-wall has a well-defined joint coated with clay. At 200 feet in depth or below water-level, the deposit was found to consist of hornblende-schist, highly charged with more or less auriferous iron pyrites. We would appear to have an instance here of contact between a dioritic mass or dyke and a schistose rock, the latter of which has become altered, for a width of 20 feet from the contact-line, into amphibolite. In the upper levels, the rock is so changed as to have become unrecognizable; but a few patches of gold were found in it, although the deposit, regarded as a whole, is a low-grade one. Have we here an instance of the contact-metamorphism of a sedimentary rock; or was the deposit originally an igneous dyke, which has subsequently become foliated by lateral pressure? At present, we do not know enough about the rocks of Western Australia to enable a satisfactory answer to be given to these questions.

What is needed is: (1) a careful geological survey of the districts in which such "formations" occur; (2) a minute microscopical examination of the various rocks contained therein; and (3) a particular study of the underground developments in the deeper mines.

One thing appears certain, whatever may have been the origin of the "formations," the present filling is largely due to the replacement of the original "country" by quartz, ironstone, etc. Such replacement has probably, in many cases, been effected by hydrothermal solutions, although a discussion of this matter is foreign to the object of this paper.

A partial replacement of large igneous dykes by lenticular masses of quartz can be seen in certain parts of the gold-fields.

At Nannine (Murchison gold-field), along the margin of Lake Annean run powerful outcrops of coarse granular talcose diorite and quartz. The strike varies from north 12½° east to north 8½° west. Several deep cuts made into the deposit, prove it to be composed of beds of quartz and schistose diorite, with a total thickness of from 30 to 60 feet, dipping east at an angle of from 45 to 50 degrees.

The quartz is sometimes in beds intercalated with the schists, sometimes it is in the form of lenticular deposits therein, and sometimes the quartz ends abruptly against cross-joints at both ends, thus forming solid blocks in the dyke or lode. In addition to the beds and blocks of quartz were cross-veins of the same mineral striking east-north-east to west-south-west, and dipping at a sharp angle south or north. In one instance such a vein was 2 feet thick, and dipped north 75 degrees. In several places, the dyke was distinctly auriferous, the gold occurring associated with iron pyrites; but the precious metal appeared to be very unevenly distributed in the dyke.

Structure.—The structure of the reefs is seldom brecciated. The wide reef-formations of the Hannan's district frequently exhibit a rough banded structure. Not infrequently there is a quartz-vein on either wall, between which is schistose filling, carrying ironstone and quartz-stringers running roughly parallel to the walls, but frequently dipping very flatly and interlacing.

The quartz-leaders are frequently high grade, while the central "formation" may be medium or even low grade. The quartz-leader, on one or both sides, is frequently absent altogether: that on the hanging-wall more often than that on the foot-wall.

At Balagundi, a schistose-ironstone formation had been cut across at a depth of 50 feet, and proved to be upwards of 20 feet in thickness. The strike was north-west and the dip north-east 70 degrees. The iron-stained quartz-leader on the hanging-wall was from 3 to 6 inches wide, that on the foot-wall being 4 inches between thin ironstone "casings." The filling between was composed of schistose "country," strongly impregnated with limonite and traversed by numerous quartz-stringers, some dipping more or less parallel to the walls, while others were nearly flat. Where the stringers interlaced patches of quartz occurred. The quartz assayed about ½ ounce to the ton, while the mullocky "country" only yielded about half that amount of gold. A vein of ironstone, 6 inches thick, striking north 54 degrees east, and dipping north-west, was observed to cross the lode here.

Sometimes the filling appears to be a crushed or jumbled mass of altered country, with quartz and ironstone in stringers and patches. Near the surface, the country is frequently altered to pipeclay or kaolin.

Fig. 4 (Plate XIII.) is a sketch of a reef-formation a few miles south of the Great Boulder and at a depth of 38 feet from the surface. The iron leaders gave by assay only about 3½ dwts. of gold per ton, the pipeclay assayed 2½ dwts. only, while no "colour" was found in washing the white kaolin.

The quartz reefs seldom continue solid for any length, but frequently split up and become mullocky.

Figs. 5 and 6 (Plate XIII.) are from sketches taken of a reef, a little north of Niagara township. The reef, at a depth of about 100 feet from the surface, consists of a vein of solid quartz, 2 feet in width, with a few inches of mullock and quartz on the hanging-wall. The reef strikes north 70° east, and the dip is east 50 degrees (Fig. 5). About 17 feet north, the quartz is split up into two leaders, the largest being 9 inches wide, separated by mullock. The quartz on the hanging-wall side has cross-joints filled with pipeclay, and between the two leaders are a few thin, flat, segregated veins of quartz (Fig. 6). These cross-joints will be referred to later.

The reef-formations frequently exhibit no hanging-wall. This is also the case with the wide lodes of Southern Cross.

Fig. 8 (Plate XIII.) is an example from a claim a little north of Hannan's Lake. The depth from surface is about 50 feet. Here a quartz and ironstone leader or "indicator," about 9 inches wide, lies on the foot-wall. Next it comes an irregular ironstone-quartz formation, separated from 8 feet of schistose ironstained formation by a joint coated with yellow clay and oxide of iron. No distinct joint separates the 8 feet of formation from the ordinary schistose "country," but the former ceases to be ironstained beyond the dotted lines shown in the figure. The best ore (containing coarse and fine gold in about equal proportions) is on the foot-wall side, and assays upwards of 18 dwts. of gold per ton, while the 8 feet of formation carrying fine gold only contains about ½ ounce to the ton. The strike of the lode is about north-north-west to south-south-east, and the dip is east-north-east 75 degrees.

East-and-west reefs often carry "formation" exhibiting a roughly banded structure.

Fig. 9 (Plate XIII.) is sketched from an east-and-west reef between the Great Boulder and Hannan's Lake, close to the surface. The dip is nearly vertical. The reef is 4 feet in width; half of it consists of white

quartz streaked with ironstone and with thin ironstone casings; the other half is "formation" with ironstone. The former assays about 8 and the latter 5 dwts. per ton.

Generally there is more gold in the quartz than in the formation itself. There are, of course, exceptions to this rule.

Fig. 10 (Plate XIII.) is one seen in the Forty-two Mile district. In this instance there is a leader of quartz on the hanging- and one on the foot-wall, the centre being composed of 9 inches in width of gossan or ironstone-formation. The quartz-veins or ribs assay only about 6 dwts., while the formation between runs nearly 9 ounces of gold to the ton, *i.e.*, at the particular point examined. The quartz is brown or light bluish in colour, and carries some iron pyrites. The reef trends east to west, but the strike is variable, and dips north 60 to 65 degrees in "country" which is probably a gneissose granulite.

At one mine at Southern Cross, at a depth of 120 feet, the structure shown in Fig. 7 (Plate XIII.) is seen in one face of the drift. On the well-defined foot-wall is a leader of sugary quartz and limonite 18 inches wide. Upon this rests what appears to be altered green schistose "country" seamed vertically by thin ironstone-layers or joints. Next to this, forming the ill-defined hanging-wall, rest more solid bands of "country" alternating with thin schistose bands for a width of 19 inches. This is divided in the middle by a seam of clay and quartz. The leader on the foot-wall assayed 18 dwts., while the rest of the filling only gave 1¼ dwts. of gold per ton.

A very characteristic feature of the quartz-reefs of these gold-fields is the frequency with which they are broken up by cross-joints or planes generally perpendicular to the dip. As these joints sometimes have a favourable effect on the gold-contents or the reverse, they are worthy of special study. Some writers regard this cross-jointing of the reefs as the result of the natural or artificial lowering of the so-called "water-level." The probability is that cross-jointing is the result of shrinkage after solidification. Above water-level, the joints would have a tendency to widen and become filled with clay, etc.

Fig. 11 (Plate XIII.) is rather a curious example taken at a depth of 76 feet from a reef at Southern Cross which strikes north 37° west, and dips to the south-west. The average thickness is about 8 feet. In the upper portion of the face the hanging-wall side consists of quartz in solid ribs; schistose "country" with ironstone lies on the foot-wall side. In the lower portion the positions of these rocks are reversed. It would appear as if the quartz was once in the same plane. A fracture then

took place from *A* to *B*, and the lower portion was heaved a little to the right (north-east). This fracture was afterwards filled up with quartz. The quartz is crossed by joint planes dipping flatly to the north-east, in other words they are perpendicular to the dip of the reef. The joints in this case are not traceable in the mullock and ironstone filling, nor are they traceable in the "country" itself. At a depth of 120 feet in the same mine, there is a rib of quartz on the foot-wall side of the reef, the rest of the filling consisting of schistose country crossed by similar joint-planes. The latter are traceable in other parts of the reef, and seem to act favourably on the gold contents.

The so-called "western" lode of the Great Boulder mine, which was first discovered about 850 feet south of the engine-shaft, is, above water-level, a reef-formation several feet in width, showing cross-joints similar to the reefs at Southern Cross.

A few miles north of Coolgardie, there is a kind of reef-formation composed of several layers or bands of quartz separated by mullock. The width is about 5 feet, the trend north-north-west to south-south-east, and the dip east 75 degrees. The quartz-layers are, more or less, lenticular in shape, and are apt to widen out and thin away suddenly. They occasionally unite, and are characterized by being divided horizontally by cross joints which have broken up the quartz into loose horizontal wedge-shaped pieces. The depth from surface in this instance is only about 30 feet.

In another reef, in the same mine, striking north-west to south-east, and dipping north-east, the quartz is divided up by nearly horizontal cross-joints which pitch flatly to the north-west. The depth from the surface is about 50 feet.

Fig. 12 (Plate XIII.) is an interesting case taken from a reef at the Day Dawn (Murchison gold-field). The hanging-wall side consists of solid bluish and grey quartz. The foot-wall is mullock with stringers of ironstone. The reef strikes about north 32½° west to south 32½° east. The dip is west 70 degrees, and the average thickness is 3 feet. It will be noticed that the cross-joints of the reef are continued as black stringers in the "country," but dipping flatly with the reef. (Depth about 50 feet.) In this mine, it is considered an unfavourable indication when the cross-joints in the quartz carry clay, but the ironstone stringers coming in at the sides are regarded by the miners as "feeders." The cross-joints or planes in this instance may have been produced by pressure acting in the direction of the arrows. When the hard quartz was met with, the cleavage, if it may be described as such, took place

along the line of least resistance, or at right angles to the plane of the reef. On the foot-wall side is a band of mullock, which is harder nearer the quartz-vein than it is next the foot-wall. The gradual bending or refraction of the planes when crossing this band of mullock is noteworthy.

An equally instructive example is to be met with in a mine, near Broad Arrow. Here the joints in the "country" dip 75 degrees, while their dip in the quartz is 67 degrees, or there is a bending or refraction of 8 degrees.

Frequently the mullock on the sides of a vein is very soft, in which case the joint-planes will not be traceable therein.

Fig. 13 (Plate XIII.) is from a reef in the Nannine district, close to the surface. The cross-joints here are traceable in the solid quartz, and in the layers of quartz, ironstone, and mullock on the east side of it, but cannot be seen in the soft jumbled "country" on the opposite wall.

In Fig. 14 (Plate XIII.), sketched from the same reef, the cross-joints are visible in the quartz, but not in the mullocky bands at the side or traversing it.

The joints sometimes traverse the reef in an oblique direction. Fig. 15 (Plate XIII.) is sketched from a reef a little south of Coolgardie—depth about 40 feet from surface. The vein is of quartz, about 12 inches thick, and the assay-value is 7 dwts. of gold per ton only. The strike is nearly north and south, while the dip is west 44 degrees. The cross-joints also dip west, but very flatly (12½ degrees), forming an angle of 31½ degrees with the foot-wall of the vein.

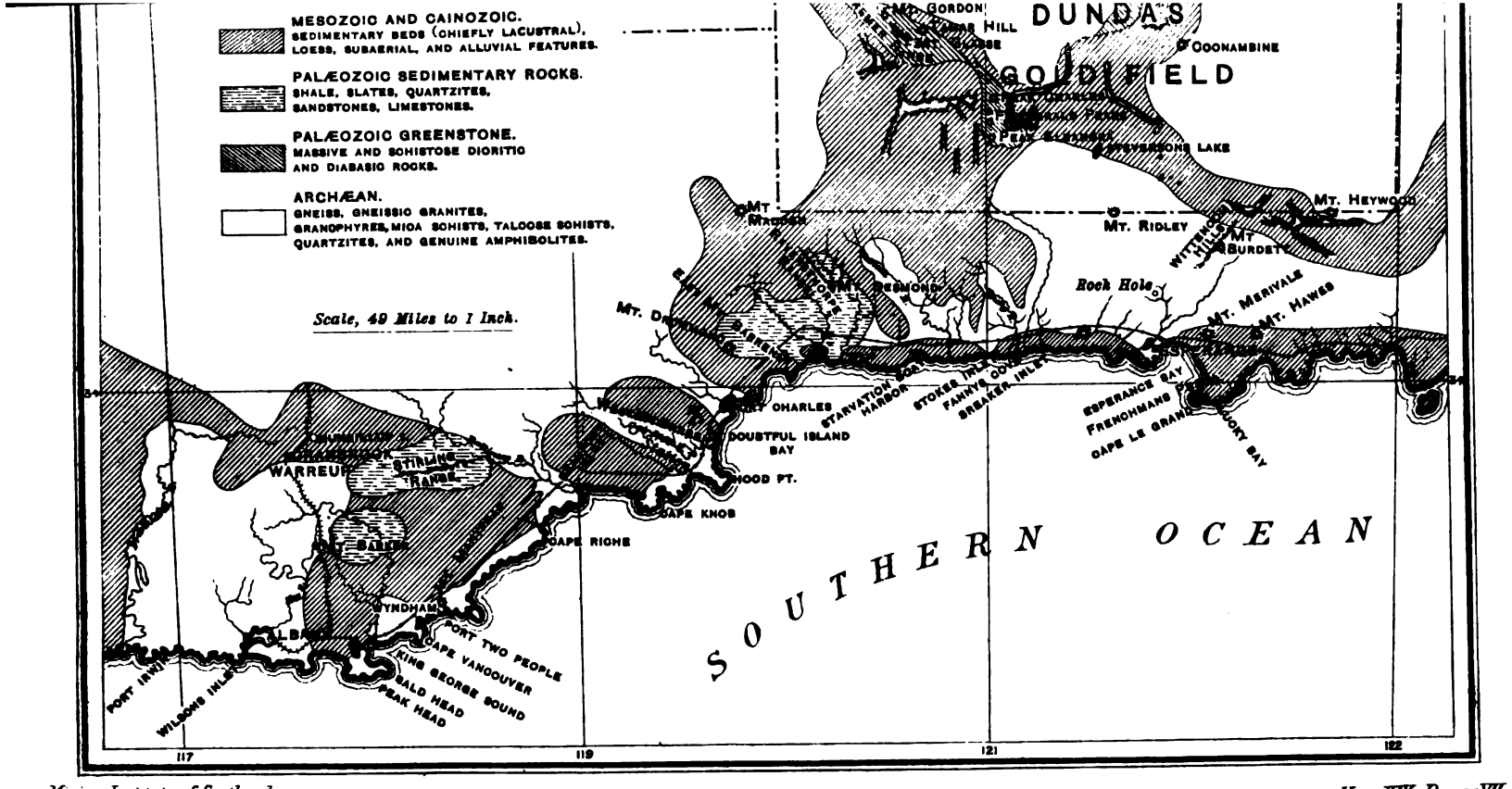
Fig. 16 (Plate XIII.) is an example of the joints crossing a flat reef near the Broad Arrow. The dip of the cross joints in this mine varies from 35 to 67 degrees.

Near Siberia, a quartz-reef striking north 52 degrees east, dipping north-west 75 degrees and about 3 feet thick is, at a depth of 25 feet, divided up into lenticular pieces by joints dipping south-east 30 degrees. About 30 feet north-east of this point, measured horizontally, and a few feet below it vertically, the filling is ironstained quartz containing flakes of whitish talc. The reef is here crossed by joints which dip south-east 40 degrees. The joints sometimes have thin layers of clay between them. A sample taken from the first point assayed 2 ounces of gold per ton, while one from the latter yielded only 14½ dwts. As has been observed in another district, where the cross-joints are open and lined with clay, there is a marked falling off in the gold contents. The "country" here consisted of light green schistose diorite, in layers dipping

from 25 to 60 degrees in a south-easterly direction, or more or less parallel with the joints crossing the reef.

One remarkable "formation" occurs not far from the Hannan's Reward mine, Kalgoorlie, and is apparently about 200 feet in width. The course is north-west to south-east, and the dip south-west about 50 degrees. On the hanging (south-west) side is a so-called reef 3½ feet in width, consisting of a leader of ironstained quartz a few inches in width, on which lies altered schistose "country" impregnated with ironstone, quartz, and clay. Below the quartz-leader there appears to be a "band" of altered diorite, brown in colour. On the foot-wall side is another so-called reef, 3 feet in thickness, consisting of a rib of hard quartz with ironstone "casings" 12 inches wide, resting on altered schistose "country" with stringers of quartz and ironstone. Between these two so-called reefs, the whole ground, for a width of upwards of 200 feet, is interlaced with ironstone and quartz-stringers, some dipping west, others east, and not a few being nearly horizontal. The entire filling between the walls, with the exception of two "bands," contained little or no gold (from nothing to 1 or 2 dwts. per ton). The two "bands," one 10 feet and the other upwards of 30 feet wide, assayed about ½ ounce to the ton; but no lines of demarcation separated these bands from the rest of the filling. The reef on the hanging-side assayed about 6 dwts., and that on the foot-wall side from 9 to 15 dwts. At a depth of 160 feet, hard blue diorite, dipping south-west and impregnated with iron pyrites, was met with on the foot-wall side. It seems highly probable that the whole deposit below water-level will be found to be one large diorite-dyke, which, near the surface, has been altered into a kind of stock-work of quartz-and-ironstone leaders. It should be noted that quartz-stringers are apt to cross the lode dipping south-east at a steep angle, and where they cross the miners say the gold is temporarily cut off. It should also be observed that the main joints in the diorite strike north-west to south-east and dip south-west, while another set crosses them north-east to south-west and dips south-east. The above quartz-stringers appear then to follow the cross joints.

One reef near Kanowna, at a depth of 132 feet, is composed of a "leader" of milky white quartz on the hanging-wall side, resting upon 2 feet in thickness of ferruginous clayey mullock, stained black here and there, and containing boulders of hard diorite or diabase. The "country" appears to be an altered schist. The reef strikes north 50 degrees east, and the dip is north-west 82½ degrees. The quartz-leader assayed 5¼ dwts., while the mullock on which it rested yielded about 4½ dwts. of gold per ton.



Mining Institute of Scotland. Transactions 1897-8

And.r Reid & Compy Ltd. Newcastle on Tyne.

Vol. XIX. Plate VII.

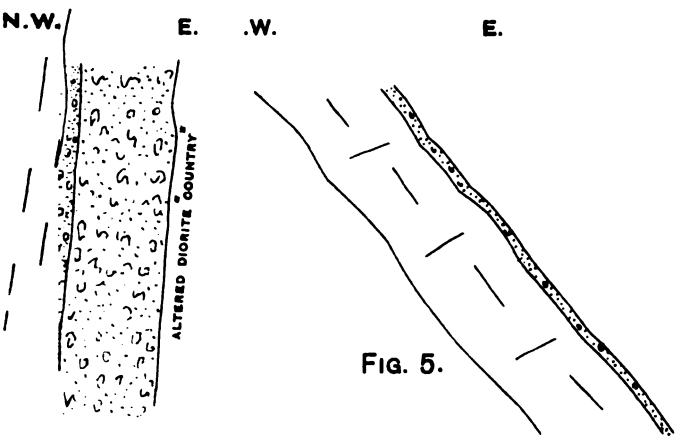
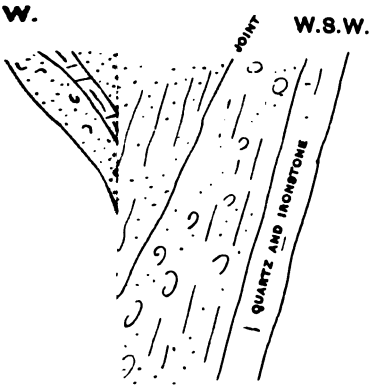


Fig. 5.



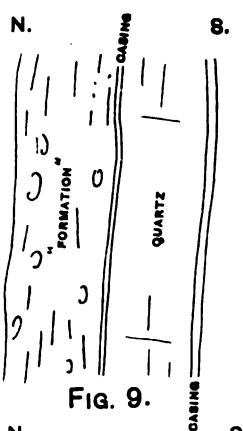


Fig. 9.

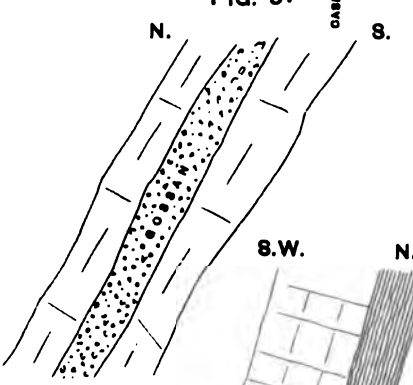
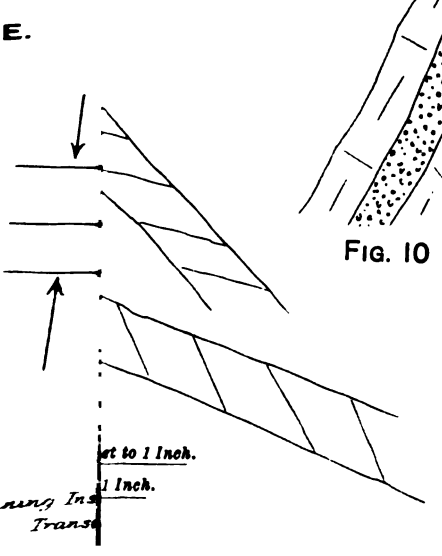


Fig. 10



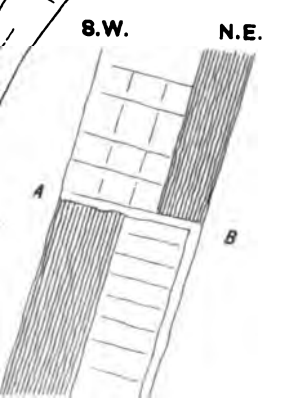


Fig. 11.

South of the same township, the writer has observed a wide conglomerate-bed composed of hard diorite-pebbles cemented by clay, etc., and which, tested at a depth of 50 feet, was distinctly gold-bearing. The bed trended north to south, and dipped east 50 degrees.

Mr. A. H. Bromly (London) suggested that the silvery white telluride mentioned as possibly a variety of sylvanite might be altaite, or lead telluride, which had been found to occur in Burma.* At Chouk-pazat, it is found below the decomposition-line. The quartz, although sometimes white, is mainly blue, and very similar to the Mysore reefs mentioned by Mr. Halse, and the altaite is found in the blue quartz. Although altaite is here non-auriferous, gold is frequently found associated with it. The blue quartz is considerably richer than the white, and when in addition the lead telluride is seen, the ore becomes above average value. It would be interesting to know whether experience shows any of the telluride-bearing reefs of Western Australia to bear the characteristic of Chouk-pazat, in that the pyritic ore is less troublesome in milling than the oxidized surface-ores.

The Chairman moved a vote of thanks to Mr. Halse for his valuable paper, and the motion was cordially approved.

Mr. A. R. Sawyer's paper on "The South Rand Coal-field, and its Connexion with the Witwatersrand Banket Formation," was taken as read :—

* *Trans. Fed. Inst.*, vol. xii., page 513.

THE SOUTH RAND COAL-FIELD, AND ITS CONNEXION WITH THE WITWATERSRAND BANKET FORMATION.

By A. R. SAWYER.

Part I.—Coal.

(1) *General.*—The writer read a paper on the South African coal-formation before the North Staffordshire Institute of Mining and Mechanical Engineers in 1889, in which he fully described the coal-seams which he had seen in the Transvaal, and discussed their origin and geological position.*

It is now his object to describe a portion of this immense tract of Coal-measures, which he has named the "South Rand coal-field," one which he has explored personally, and in which he has discovered a very valuable coal-seam, quite above the average.

The coal-bearing measures which were formed during the Triassic age were deposited in numerous more or less basin-shaped depressions and hollows. These depressions and hollows were formed by the denudation of older rocks of different ages. The deposits, though of contemporaneous formation, are distinct coal-fields, separated from each other by the old rocks which have survived denudation.

These coal-fields are of two kinds: larger ones in which the coal occurs at depths of some hundreds of feet, and smaller ones in which the coal occurs at shallow depths of from 40 to 200 feet.

If the coal be of subaqueous origin, as believed by the writer, the vegetable matter of which it is composed will have been carried further from the margin of the basin in a large coal-field than the mud which has been carried into the basin at different times. In smaller coal-fields, the distance from the margin being so small, the vegetable matter will be very much more mixed with mud. In proof of this contention, the coal found on the farm Modderfontein, which is close to the margin of the South Rand coal-field, is of very inferior quality, and the coal-seam is thin. The usual characteristic of South African coals, from shallow formations, is that they consist of alternating laminæ of coal and impure carbonaceous matter, which further supports this view.

* *Trans.*, vol. x., page 161.

The writer may also state that the coal-field which he is about to describe, and which is contained in a basin of large extent, viz., 400 square miles, compared with coal-fields at present worked, contains in its centre a thick coal-seam in which the coal is practically free from the usual carbonaceous laminæ. This coal-field lies, as shown in Fig 1 (Plate XIV.), between the so-called Upper and Lower Rooi Kopjes (Red Hills) about 16 miles south of the town of Heidelberg. It is bounded on the east by the Upper and on the west by the Lower Rooi Kopjes, and to the north in part roughly by a range of quartzite-hills. To the south, as will be shown later on, the Coal-measures are disturbed near the Vaal river, where numerous dykes of basic igneous rocks occur.

Coal-measures have been found in the Orange Free State across the Vaal river, by the writer, at Viljoen's Drift, where he advised a borehole to be put down for Messrs. Lewis and Marks. The Vereeniging is distinct from the South Rand coal-field, and is about 25 miles distant from it.*

A borehole, which had been put down at Kroonstad to a depth of 800 feet was continued by the writer's advice, and a coal-seam was found at a depth of about 900 feet (about 8 feet thick), but this was of very inferior coal and quite unworkable.

Historical.—A description of the South Rand coal-field would be incomplete without a short history of the South Rand Gold Corporation, Limited, which corporation practically owns and controls it. In 1893, the writer acquired property in this locality, in conjunction with Mr. James Heath, M.P., having previously formed the opinion that an important coal-field lay between the Upper and Lower Rooi Kopjes. The writer obtained the coal rights over this area, and he issued a plan showing the boundaries of what he supposed to be the coal area, dated September 6th, 1894, which was printed. The Witkleifontein Syndicate was formed in London, mainly through the instrumentality of Messrs. Heath and C. G. Sawyer. The Heidelberg Union Land Co. was subsequently formed to acquire the interests of the Witkleifontein Syndicate, and to enlarge its holding so as to obtain the control of this coal-field. The South Rand Gold Corporation, Limited, was afterwards formed to acquire all the assets and interests of the Heidelberg Union Land Co., Limited. The writer has acted as sole representative of and engineer to the Syndicate, the Heidelberg Union Land Co., Limited, and to the South Rand Gold Corporation, Limited, in Africa.

* *Trans. Fed. Inst.*, vol. xii., page 186.

The first borehole, to prove the writer's opinion as to the presence of a valuable coal-seam in this coal-field, was put down on the farm Modderfontein on the outskirts of the coal-field. The next borehole was put down in the centre of the coal-field at Beerlaagte. At 102 feet 8 inches from the surface, a mass of igneous rock was encountered. Finding it on examination to be dolerite, and believing it therefore to be a sheet, the writer continued boring until he was through it, although its total thickness was found to be 340 feet 4 inches. At a depth of 550 feet, a seam of good coal, 25 feet thick, was intersected.

A third borehole was put down at Grootvlei, with the result that he there found the igneous sheet to be only 25 feet thick and the coal-seam 60 feet thick, the coal being of excellent quality, better than any he had seen in South Africa. On the strength of these results, a circular shaft was sunk, 11 feet in internal diameter, 1,600 feet distant from this borehole. Substantial colliery buildings were also erected. These works were supervised by Mr. Evan Williams, colliery manager.

Coal-measures.—These Coal-measures are part of the extensive coal-bearing formation overlying the Karoo formation in the Orange Free State and Cape Colony.

In this locality, they rest, as shown on the accompanying sections (Fig. 2, Plate XV., Fig. 3, Plate XVI., and Appendix A), on gneissoid granite in the centre, and on rocks of the Witwatersrand Banket formation at the sides. The rocks consist of sandstone, grit, conglomerates, clay-slate, shale, limestone, and ironstone.

The sandstone occurs laminated and compact, occasionally as flagstone. In some instances it is fine and in others coarse-grained. It is more or less micaceous, the mica causing it at times to split up into laminæ, and at other times to form a mica-schist. The sandstone exhibits well-marked false-bedding, while some bands of it contain nodules of perfectly globular iron pyrites, up to 4 inches in diameter. These balls occur occasionally joined together. At a depth of about 300 feet in the shaft, a bed of open and friable sandstone occurs, which contains good sized waterworn quartzite-pebbles. The sandstone is occasionally calcareous.

The grit is dark and coarse, and contains pebbles.

The shale is at times dark, carbonaceous and micaceous.

The limestone occurs occasionally in thin white bands.

The ironstone occurs in the shaft in a lenticular mass and resembles blackband ironstone. It also occurs in masses on the surface near the

centre of the coal-field; this deposit has not yet been proved. It also occurs in thick deposits resembling bog iron-ore.

Breccia.—At the bottom of the Coal-measures, a more or less thick bed of breccia occurs, but does not extend invariably all along the edges of the coal-field. It varies in thickness from a few feet to 251 feet, but its average thickness is about 60 feet (Figs. 3 and 4, Plate XVI., and Appendix A).

The blocks and pebbles consist of quartzite and quartz (derived from the Banket formation), gneiss, shale, etc. The occurrence of brick-red grains is characteristic. The pebbles are sometimes rounded. The breccia is in some places interstratified with thin beds of shale and sandstone, and at other places it rests immediately on the gneiss, and on the Banket formation at the edges. It occurs in the centre of the coal-field at depths of from 388 to 704 feet, and it is thickest where it lies deepest. The matrix consists in part of quartzite-grains and fireclay. Traces of gold occur in this breccia, where the blocks and pebbles consist of quartzite derived immediately from the adjoining auriferous beds.

The writer has alluded to the possibility of this breccia being contemporaneous with the Dwyka Conglomerate, in his report to the Cape Government on the *Mineral Resources of the Division of Prince Albert* in 1893, and the results lately obtained by him have not caused him to change his opinion.

It appears that Prof. Schmeisser found a rock near Boksburg which he correlates with the Dwyka Conglomerate.* At Viljoens Drift, in the Orange Free State, a similar bed occurs at depths varying from 510 to 580 feet in which the pebbles are more flinty. The matrix is dark grey and white. It rests on grey and slightly pink dolomitic limestone.

Dolerite.—As in other portions of the Coal-measures of South Africa, dolerite occurs in this coal-field, but, as will appear presently, under peculiar circumstances.

Two dolerite-sheets occur. The upper dolerite-sheet varies in thickness from a few feet at Rietvlei to 341 feet at Beerlaagte. It has a long lenticular form, and its highest horizon is at Beerlaagte near the centre of the coal-field, where it crops out along the sides of a large circular "pan" (hollow or depression). From this point, it slopes down slightly on either side. To the west, at Beerlaagte, it is found in No. 2 borehole at 103 feet

* *Trans. Fed. Inst.*, vol. xi., page 400.

from the surface, and at No. 7 borehole at 109 feet, but owing to the configuration of the ground, at a really lower level. The sheet also apparently thins out on either side as it leaves the pan, but much more rapidly to the east, where at Grootvlei, in the shaft, it is about 34 feet thick, and farther east, at Rietvlei, it dwindles down to 2½ feet. Westwards, the decrease in thickness is not so great: at No. 2 borehole (Beerlaagte) it is 341 feet thick, and at Witkleifontein 262 feet thick (Fig. 2, Plate XV.).

The lower dolerite-sheet is only 8 feet thick at Beerlaagte and evidently thins out westwards, as it has not been found in No. 7 borehole at Witkleifontein. It extends eastwards and is 7 feet 6 inches thick at Grootvlei; it then thins out, as it is not found at Rietvlei. (Fig. 2, Plate XV.).

In conformity with the accompanying strata, the upper sheet has been found to rise slightly eastwards from Grootvlei, as seen in the section of the shaft and No. 5 borehole (Fig. 3, Plate XV.). It also rises, but more abruptly at Rietvlei. It evidently crops out in places towards the Vaal river, owing to surface-denudation due to its tributaries.

Coal has thus been discovered for the first time beneath dolerite-sheets, in the Transvaal. The sheets are, however, so far distant from the coal-seams that they have had no effect whatever upon it. Calcite and pyrites in large cubes occur frequently in the cracks of the dolerite, enclosing pieces of the igneous rock. The dolerite contains numerous vertical or nearly vertical joints (columnar structure) which frequently show a coating of silky-black serpentine. This dolerite is mostly ophitic, and consists of augite, lath-shaped crystals of plagioclase-felspar, dust magnetite and labradorite (glomero-porphyritic groups), olivine, and small quantities of ilmenite. The crystals of augite are often larger, but include so many crystals of labradorite that they appear quite fragmentary (ophitic). The olivine is often very much cracked, and has been replaced along these cracks by serpentine. Olivine-basalt also occurs with a ground-mass of radiating and matted lath-shaped felspars, with granular augite and dusty magnetite, in which are porphyritic crystals of labradorite and serpentinous pseudomorphs after olivine.

The question arises, are these sheets sub-aerial (interbedded) or intrusive? The description of the rocks in the borehole section (Appendix A) is given as they first presented themselves to the writer, and from this it would be thought that he considered these sheets to be intrusive (which was his first impression), but after systematizing all his facts he believes that they point more to a volcanic origin, and that

these sheets are sub-aerial. His principal reasons for this view are :— (1) They appear to conform with the bedding of the rocks among which they are intercalated ; (2) the overlying strata are not broken into or disturbed ; (3) their lenticular shape and the relative position of the upper sheet at various localities, pointing to a flow downwards in either direction from the pan, where possibly the vent may be situated ; the rise of the sheets eastward from Grootvlei is due to a subsequent curvature of the measures which the sheet shared ; (4) their uniformity : they present a pronounced and very frequent columnar structure ; (5) they are associated with bands of tuff, and the upper and lower beds of sandstone in which they occur are mostly interlaminated with tuff ; these tuff-laminæ the writer at first mistook for indurated shale, hence his first opinion that they were intrusive, but he considers that they afford indications of feeble intermittent volcanic explosions whereby light showers of dust were discharged, which settled down quietly amidst the sand accumulating at the time.

Another reason, for his first view, was that the dolerite was more crystalline in the central portions of the sheet, but he now attributes the more close-grained texture at the top and bottom of the sheets to an intermixture of tuff. The fact that the dolerite was very rarely cellular or amygdaloidal also influenced him in his first opinion.

Should the writer's view be the correct one, and the presence of a vent established at the pan, it would be interesting to know what effect the great heat and pressure which must have accompanied the outflow of this immense mass of lava had on the thick seam of coal, which it passed through, at the contact. The character of this dolerite is identical with that of the dolerite-sheets surrounding the diamantiferous pipes at Kimberley, and some of the dolerite in the boreholes had a very bluish appearance.

In connexion with this matter, the occurrence of a disturbance on the farm Rietvlei (near the Vaal river) should be mentioned, where Coal-measures sandstone has been tilted up so as to dip at an angle of 30 degrees. This sandstone is laminated, quartzitic in part, and forms excellent building-stone, which is quarried. It dips away from a pan, which is situated about 1,200 feet from it, and around which yellow clay, waterworn pebbles, and loose pieces of indurated clay occur.

Coal.—Reference has already been made to the coal-seam occurring in the South Rand coal-field. There is actually only one workable coal-seam, with a thin rider about 30 feet above it, and a 1 foot seam beneath

it. This seam is somewhat broken up, and loses in quality, to the north, on the farm Modderfontein. Its average thickness is 25 feet, but it is 60 feet thick at Grootvlei, where the colliery is established.

If all carbonaceous bands were deducted from the estimated thickness of most South African coal-seams, this coal-seam would be found to be far and away the thickest.

Trials of this coal taken direct from the mine, without any sorting, were made at the Robinson gold-mine by Mr. Seymour, engineer to the Rand Mines, Limited, and his report is appended hereto (Appendix B). The coal was stated by him to be 29 per cent. better than the best coal used at the Robinson gold-mine. It is remarkably free of sulphur, and contains very little ash.

The colliery consists, at present, of a single shaft 11 feet in diameter. It is 582 feet 4 inches deep, including a sump 20 feet in depth. The iron headgear is 60 feet high, and a proper staging is also erected. The coal-seam is being opened out, and the coal so produced is being sold. Part of the shaft is lined. There is no large feeder of water, and that made in the mine is easily wound to the surface.

Breaks and Faults.—There does not appear to be a single break or fault in the whole coal-field. The formation lies practically horizontal, except at Rietfontein as previously mentioned. This horizontality is a marked characteristic of the South African coal-formation.

Fossils.—A fossil tree was found in the shaft at Grootvlei, but it was too much broken up to enable anyone to decide definitely as to its nature. A few impressions of leaves were found in a clay-shale bed and some lepidodendroid fossils in the coal-seam, but otherwise the formation has so far proved very barren palæontologically.

Prof. De Launay has pointed out that the Transvaal Coal-measures are older than the Stormberg Series, and he consequently describes them as Karoo beds. He stated that Mr. Goldmann had put on record the find of *Lepidodendron* and *Favularia* at Vereeniging; the writer thinks it due to himself to state that it was he who discovered these two fossils, and he mentioned the fact in a paper on "Mining at Kimberley," read before the North Staffordshire Institute of Mining and Mechanical Engineers in 1889.* These fossils are in the museum of Hanley, Staffordshire.

Fire-damp.—The writer only knows of one instance in which fire-damp has been detected in any South African coal-mine. This occurrence took place on April 21st, 1892, whilst he was examining the colliery of

* *Trans.*, vol. x., page 85; and also in *Trans. Fed. Inst.*, vol. xiii., page 122.

Messrs. Lewis and Marks at Vereeniging. The seam is about 100 feet from the surface. A borehole had been put down in the workings to a lower depth, and plugged to prevent the outflow of water. The writer held his candle to this hole and had it unplugged, when a large blue flame about 3 feet long issued forth and was immediately extinguished. This was repeated several times. No fire-damp has been so far discovered in this coal-field, save a small quantity at the Grootvlei colliery.

Small Collieries.—A few small outliers of the Coal-measures are shown in Fig. 1 (Plate XIV). These consist of shallow deposits extending along the spruits or streams. The coal which they contain occurs at depths varying from 40 to 60 feet, and it is worked at one or two small collieries.

Part II.—Gold.

General.—Prospecting for gold has been vigorously carried on by the writer around and in the South Rand coal-field. His opinion that the coal-field merely covered a large area of Banket or gold-bearing formation has been borne out, and numerous auriferous reefs have been intersected.*

Banket Formation.—The geological plan and section (Fig. 1, Plate XIV. and Fig. 2, Plate XV.) show the extent of this formation, both as regards area and depth, in the locality.

From the section (Fig. 2) it will be seen that the formation consists of two sides of an anticlinal, the top part of which has been removed by denudation before the Coal-measures were deposited. These rocks were originally thrown into an anticlinal fold through the pressure of the granitic base beneath them. A comparison between this section (Fig. 2, Plate XV.) and the one accompanying the writer's paper (Fig. 1, Plate XX.) read before this Institution† will show a remarkable similarity between this formation at the Rand and in this locality. In both localities, a large anticlinal fold produced through the elevation of the granite base occurs. The thickness of the formation is about the same, and in both cases the formation is topped by a thick sheet of amygdaloidal diabase. There is no doubt whatever in the writer's mind that the western side of this anticlinal is an uninterrupted continuation of the Rand formation, with the exception of dislocations. The Rand formation at its western end (Bantjes Gold-mining Company) dips 32 degrees south, it then forms an anticlinal on the farm Doornkop, No. 331,‡ and is then hidden beneath dolomitic limestone and amygdaloidal

* *Trans. Fed. Inst.*, vol. ix., page 362. † *Ibid.*, vol. ix., page 360.

‡ See the writer's remarks in *Trans. Geological Society of South Africa*, vol. ii., page 15.

diabase, forming, no doubt, several synclinals and anticlinals until it emerges again on the farm Witkleifontein, where it dips to the north-west at an angle of 15 degrees. It may be here remarked that the writer has advised a borehole being put down at Doornkop on the top of the anticlinal, with a view to intersecting the main reef at a workable depth.

The rocks forming the western end of this formation are, in the writer's opinion, about 12,000 feet thick. Only a few hundred feet of these strata crop out, and the others are hidden by surface-soil and Coal-measures. The formation here dips north-west 15 degrees, and the occurrence of a thickness of at least 4,300 feet of strata has been demonstrated by boring.

The thickness actually proved in the upper portions of the formation is about half of that estimated.

The rocks forming the eastern end of the formation are also about 12,000 feet in thickness, and they are entirely hidden by Coal-measures in the line of section. The formation here dips at an angle of 45 degrees to the east, and the occurrence of a thickness of at least 6,000 feet has been demonstrated by boring. The thickness actually proved by boring is about 400 feet. The rocks at the eastern end differ lithologically from those at the western end: they resemble more the clay-slates and quartzites of Hospital Hill, which are older.

The Banket formation at the eastern end, beneath the Coal-measures, is shown in Fig. 4 (Plate XVI.). The determination of the contact between the quartzites discovered in No. 6 borehole and the slates discovered in No. 4 borehole was a work entailing much consideration.

Borehole No. 4 was first put down, and then No. 6 was put down to a depth of 250 feet. The quartzite proving very strong and the wear-and-tear in diamonds being heavy compared with that in the Coal-measures above, it was decided to try and get at the contact by putting down a few holes through the Coal-measures between Nos. 4 and 6 boreholes. No. 12 borehole was then put down: at 212 feet quartzite was encountered, it was passed through at 226 feet, and followed by breccia and conglomerate-beds to a depth of 241 feet, when slate occurred. 2 feet of core were lost just before reaching the slate. The conclusion arrived at was that the contact had been reached and a reef at the contact lost, so another borehole was put down (No. 13) 3 feet distant from No. 12 borehole. The results obtained led the writer to the conclusion that the quartzite passed through in Nos. 12 and 13 boreholes was not the solid rock, but a large block disconnected from it

and forming part of the bed of breccia which underlies the Coal-measures. No. 14 borehole was next put down. This also passed through a large block of quartzite with breccia and conglomerate beneath, and the slate was bored into. The best plan then appeared to the writer to bore No. 6 hole deeper, notwithstanding the hardness of the quartzite, and the contact was reached at a depth of 530 feet 10 inches.

What helped to influence the writer in his first conclusion on the result of No. 14 borehole was the fact that the quartzite-block showed distinct planes of stratification dipping, as in the solid formation, at an angle of 45 degrees. This dip shows that the blocks must have slid down from the solid without being otherwise disturbed.

The above description is given to illustrate the difficulties attending a correct deduction of phenomena shown in cores, and how much care is required to properly appreciate them. In order to convey a correct impression of the samples of cores assayed, they were sketched by Mr. G. Stanley Bloomer, and are reproduced in Figs. 8 to 120 (Plates XVII. and XVIII.

Description of Rocks.—The rocks forming the western end of the anticlinal have so far been shown to consist of quartzite: coarse, fine, and argillaceous, containing pebbles occasionally in greater or fewer quantities; slate: in very thin bands, more or less sharply defined; and Banket reefs: thin on the whole, with mostly small pebbles.

The quartzites and Banket Reefs are more or less pyritical. Pyrites occurs as segregations near pebbles, mixed with argillaceous matter and disseminated throughout the mass. It is invariably crystalline when visible to the naked eye. The pebbles consist mostly of quartz, milky white, smoky black, transparent, translucent, streaked; yellow, bluish, and horny (truffle colour); rounded, angular, and sub-angular. Slate-pebbles occur, as on the Rand,* though in greater quantities, soft and hardened, mostly small, but occasionally large, often elongated and flat. Pebbles of mica—transparent—occur at times. Grains of shale and flakes of mica also occur more or less throughout the cores.

The rocks forming the eastern end of the anticlinal consist, so far as proved, also of quartzites, slates, and Banket Reefs, but the character of the quartzites is different and the slate occurs as a very thick bed. The quartzite above the slate is extremely talcose, mostly compact, white, and very hard. A bed of quartzite older than the slate in

* This fact seems to have escaped the notice of several writers.

geological sequence has peculiar characteristics (Fig. 2, Plate XV.). It is talcose and argillaceous, has schistose planes, and is extremely hard in depth. It contains calcite and white quartz-veins; also pyrites in segregations.

The slate-bed, near the contact, at No. 6 borehole, presents certain peculiarities: it contains large white and smoky quartz-pebbles, bands of quartzite, specks and segregations of pyrites and black quartz-grains.

It has occurred to the writer that these slate-beds may have had an igneous origin, and have been basic igneous rocks in which cleavage-planes have been superinduced; but the presence of pebbles and quartz-grains in the slate, as described above, which by the way is an unusual occurrence, and so far as the writer knows has not been pointed out before, would seem to detract from this view. In connexion with the usual presence of a Banket Reef at the contact of slates and quartzites, it may be observed that the fact that no reef is intersected in any particular borehole must not be taken as evidence of its non-existence, as the slightest earth-movement may cause a sliding motion sufficient to efface it at any particular spot, the substance of the reef being thrust on to itself at another point.

The deposition of pyrites differs at the western from that at the eastern end of the section (Fig. 2, Plate XV.). At the western end, the pyrites is segregated more around the pebbles and also more regularly in the form of venules, whereas at the eastern end very few venules occur, the pyrites being more in the form of irregular segregations. As on the Rand, galena and zinc blende occur in veins of secondary quartz at the western end. These quartz-veins are white, and not more than a few inches thick.

Fig. 2 (Plate XV.) shows an underground connexion with the formation in which the Heidelberg Roodepoort reef occurs. The diabase-sheet, which covers and thus hides it, has been shown to have a maximum thickness of 3,000 feet.

In corroboration of this view, the writer may state that a borehole had been sunk to a depth of 1,050 feet on a certain property in the Potchefstroom district. The core consisted of igneous rock, and the writer was asked to report as to whether the boring should be stopped, as it was thought that the hole was in a dyke. He examined the core and the ground carefully and made the accompanying section (Fig. 5, Plate XVI.). He formed the opinion that the rock encountered so far was the amygdaloidal diabase-sheet and that it would be passed at a depth of about 1,330 feet; he therefore advised that boring should be

continued. At a depth of about 1,440 feet the sheet was passed through and quartzites encountered, some of which are auriferous.

Dykes.—Dykes occur in this locality, which are mostly of diabase. In one notable instance, a dyke of quartz-diabase was encountered in the borehole near Vlakfontein station. To all appearance this rock looked like a highly talcose quartzite, but the quartz-grains were dull and ill defined. The rock was hard, heavy, contained pyrites and numerous calcite and white quartz-veins. A microscopic examination showed it to be granophyric and to contain kaolinized felspar, augite, quite fresh, and exhibiting good twinning, magnetite, and iron pyrites. The spaces between these minerals were entirely filled with a beautiful granophyric intergrowth of felspar and quartz.

Part III.—Bed Rock.

Granite.—The gneissoid granite, forming the base of this coal-field, is part of the basement underlying the whole of South Africa, and is here, in the writer's opinion, distinctly anterior to the Banket formation. The writer has examined it at Cape Town and George in Cape Colony; in Mashonaland; in Matabeleland; and at Vredefort, in the Orange Free State.

In the Transvaal, the writer has examined it at Zoutpansberg; on the Rand; north of the farm Witfontein, No. 572;* on the farm Varkenskraal, No. 354; and 13 miles east of Heidelberg. He has also shown its position as a dyke at the eye of Wonderfontein.†

Regarding its occurrence on the farm Varkenskraal, a banket reef occurs, in the writer's opinion, over nearly the whole extent of the farms shown in Fig. 6 (Plate XVI.). The reef, and the quartzites and slates accompanying it, are covered over about two-thirds of the farms by dolomitic limestone and cherty detritus, produced by its denudation. The reef dips from the western side of the farms, where they are horizontal, at an angle of from 5 to 10 degrees to the east, and is, therefore, not likely to occur at a greater depth than 400 or 500 feet at the Mooi river, where the reef lies deepest (Fig. 7, Plate XVI.). From the western side of the farms, the reef dips westward into the proclaimed farms Zyferfontein and Wolvefontein, at an angle of about 5 degrees. On Zyferfontein, it forms several small anticlinals and shallow synclinals, and crops out with an eastern dip of about 10 degrees, about 3 miles west of the farms. From an examination of the country north of the farms, the

* *Trans. of the Geological Society of South Africa*, vol. ii., page 33.

† *Ibid.*, vol. ii., page 15.

writer believes that the small anticlinal which occurs along the western end of the farms, and which stretches towards Klerkskraal, is connected with a granite-intrusion, which occurs, as shown on Fig. 6 (Plate XVI.), on the farm Varkenskraal. Some of this granite contains white quartz-veins, which can be seen passing through various gradations of decomposition until they reach the final stage of Banket pebbles. On Varkenskraal and Klerkskraal, the Banket Reefs and accompanying quartzites are clearly seen resting upon the granite, and some of the pebbles occurring in the reef at its outcrop on Zyferfontein farm consist of glassy white quartz.

The reef varies in thickness and quality over the extent of country shown on Fig. 6 (Plate XVI.). It sometimes appears to form two distinct reefs. In some places it resembles a breccia, at others, and more generally, it resembles some of the best Banket beds of the Rand. It contains mostly average-sized quartzite-pebbles. In some places, large sandstone-pebbles occur, as much as 18 inches long. Occasionally the pebbles are small. The foot- and hanging-walls also vary. At Zyferfontein, and at a few other places, they consist of slate. On the other farms, the hanging-wall is usually quartzite. The writer is of the opinion that this reef more nearly resembles the Black Reef, and more especially as it occurs at Eastleigh, than any other Banket Reef that he knows. It was impossible, in view of the large quantity of banket traceable, to do more than to pan a few promiscuous samples. On the whole, the results were satisfactory, and several pannings showed 8 or 10 dwts. of gold to the ton, which, in some cases, was very coarse.

The writer has referred to his discovery of granite at a place east of Heidelberg, at a meeting of the Geological Society of South Africa.* Its position is now shown on the accompanying geological plan (Fig. 6, Plate XVI.). Granite is nowhere seen near the surface in the neighbourhood of the South Rand coal-field. It was intersected in boreholes in the centre of the coal-field at depths of 687 feet and 725 feet respectively.

This granite is pink in appearance. Rock-slides of samples of these latter gneissoid granites were made, and these were seen to resemble the protogine gneiss of Mont Blanc. The minerals thus found were:— Felspars (monoclinic and triclinic) and quartz, all more or less abraded at their edges, cemented together by thinnish bands of chlorite (secondary from brown mica), fibrous hornblende, and protogine (a secondary white mica). A porphyritic pink crystal (beautiful microclines), also abraded

* *Trans.*, vol. i., page 36.

at its edges, was observed; on examination, under polarized light, it was seen that large pieces of this crystal had been broken off by crushing agencies, and yet only slightly moved before being cemented together to the main portion of the crystal by protogine.

The writer is indebted to Mr. P. D. Durell, who kindly drew all the illustrations reproduced in Plates XIV., XV., and XVI. attached to this paper.

APPENDIX A.—Section of No. 5 Bore-hole at South Rand Colliery, Grootvlei, commenced on September 9th, 1895, and completed on January 2nd, 1896. The Diameter of the Bore-hole is 3¼ Inches, and of the Core 2½ Inches to the Bottom of the Bore-hole.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Yellow clay ...	16	0	16	0
2	Yellow clay and pebbles	13	0	29	0
3	Clay, gradually getting darker and more micaceous ...	35	0	64	0
4	Soft grey shale, more or less micaceous...	16	6	80	6
5	Shale...	0	10	81	4
6	Soft grey shale ..	26	8	108	0
7	Calcareous shale ...	1	10	109	10
8	Shale, more or less arenaceous ...	0	8	110	6
9	Shale, slightly calcareous and arenaceous	1	6	112	0
10	Shale, arenaceous ...	1	0	113	0
11	Shale, arenaceous and micaceous (harder)	1	0	114	0
12	Shale, arenaceous and micaceous (indurated at contact)...	4	0	118	0
13	Dolerite	25	4	143	4
14	Slate, indurated ...	0	2	143	6
15	Sandstone, indurated (quartzite) with much pyrites ...	0	6	144	0
16	Sandstone, coarse in part ...	78	0	222	0
17	Shale, arenaceous and partly micaceous ...	15	6	237	6
18	Shale, micaceous and arenaceous ...	4	0	241	6
19	Sandstone, coarse and fine, with a few thin and irregular bands of shale in places	89	4	330	10
20	Sandstone, fine, more or less micaceous in part	59	2	390	0
21	Alternating thin bands of sandstone and dark micaceous shale	13	4	403	4
22	Fine black shale slightly banded in places	15	8	419	0
23	Sandstone, coarse ...	1	0	420	0
24	Sandstone, pure white	0	3	420	3
25	Sandstone, coarse ...	0	3	420	6
26	Shale, dark	3	3	423	9
27	Fine sandstone, with shale-bands ..	2	3	426	0
28	Sandstone, coarse and fine ...	9	4	435	4
29	Carbonaceous shale and coal	1	6	436	10
30	Sandstone	31	2	468	0
31	Agglomeration of quartz-grains in a pyrites matrix .	0	6	468	6
32	Shale, highly carbonaceous, with bands of coal ..	7	1	475	7
33	**COAL**, mostly very bright and light with duller bands; only 7 feet of core recovered; remainder must be better coal...	11	1	486	8
34	Carbonaceous shale-band	1	0	487	8
35	**COAL**, with carbonaceous shale ..	1	2	488	10
36	**COAL**, good	16	8	505	6
37	Carbonaceous shale	0	3	505	9
38	**COAL**, good .	1	4	507	1
39	**COAL**, good ...	2	9	509	10
40	Shale, highly carbonaceous	1	6	511	4
41	**COAL**, very good ..	9	2	520	6
42	**COAL**, very good ..	6	0	526	6
43	Sandstone, coarse ...	27	6	554	0
44	Sandstone, finer, with carbonaceous impurities and quartz-pebbles	15	0	569	0

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
45	Sandstone, coarse, with carbonaceous impurities	9	0	578	0
46	Dark coarse grit, with pebbles ...	1	0	579	0
47	**COAL**, very good...	1	0	580	0
48	Sandstone, more or less fine, with bands of coarse grit ...	18	0	598	0
49	Dark coarse grit, with pebbles ...	4	6	602	6
50	Slightly calcareous grey earthy soft rock : decomposed igneous rock ...	1	0	603	6
51	Dolerite-sheet ...	7	6	611	0
52	Mica	0	6	611	6
53	Coarse grit, with carbonaceous impressions and laminæ with a few pebbles	28	6	640	0
54	Shale, carbonaceous	4	0	644	0
55	Coarse grit, more or less dark grey	8	9	652	9
56	Grey shale, with white bands ...	7	3	660	0
57	Breccia, with large pebbles of quartzite and shale, with small brick-red grains ...	27	0	687	0
58	Gneiss, coarse-grained, with pink felspar, jointed, 45 degrees	40	0	727	0

APPENDIX B.—Boiler test of South Rand coal begun at 12 noon on August 26th, 1897, and ended on the following day at 10 a.m. The two boilers used were coupled return tubular, with return side-flues, connected at the top and bottom by the steam-drum and mud-drum respectively, and were supplying steam to a triple-expansion vertical engine, and to a compound vertical Riedler air-compressor at the Robinson 120 stamps battery. The boilers had 2,397 square feet of water-heating surface, 58 square feet of grate-surface, 44 tubes of an outside diameter of 3½ inches, and 16 feet in length between tube-sheets.

Experimental Data.

Average height of barometer, corrected, inches...	24·45
,, atmospheric pressure in pounds per square inch ...	12·014
,, draft in inches of water	0·187
,, temperature in degrees Fahr. of boiler-house ...	70·46
,, ,, ,, ,, feed-water	69·16
,, ,, ,, ,, uptake-gases ...	433·56
,, pound pressure per square inch by the steam-gauge...	119·00
,, ,, ,, ,, of the steam, absolute	131·014
Percentage of moisture in the steam	0·50
Temperature in degrees Fahr., corresponding to absolute atmospheric pressure	347·652
British thermal units in each pound of feed-water	69·1789
,, ,, dry steam	1,219·6753
Pounds of wood used to light the fires	387·00
,, coal fired	9,098·75
,, cinders remaining	143·20
,, coal consumed	8,955·55
,, clinkers in the coal	404·80
,, ashes in the coal	836·70
,, moisture in the coal	159·22
,, total refuse	1,400·72
,, combustible in the coal	7,554·83

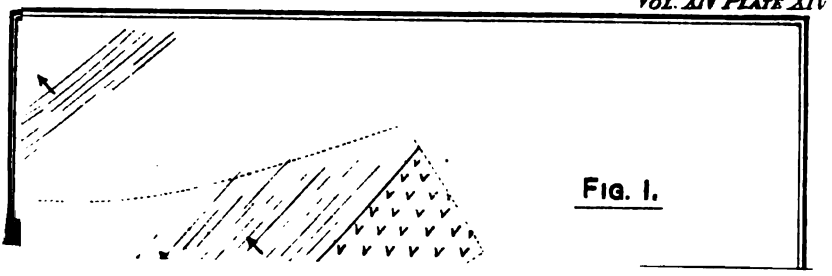


Fig. 1.

Percentage of combustible in the coal	84·359
,, clinker ,, ...	4·520
,, ash ,, ...	9·343
,, moisture to coal consumed	1·778
,, total refuse	15·641

RESULTS.

British thermal units absorbed by each pound of feed-water...	1,150·7963
Factor of evaporation	1·1916
Pounds of water evaporated into dry steam	60,536·00
,, ,, ,, per pound of coal	6·5703
,, ,, ,, ,, combustible	7·7483
,, ,, ,, ,, coal from and at 212° Fahr.	7·8291
,, ,, ,, ,, combustible from and at 212° Fahr.	9·2328
,, ,, ,, per square foot of heating-surface per hour	1·147
Pounds of coal burned per square foot of grate-surface per hour	7·22
British thermal units per pound of coal absorbed by the feed-water	7,561·076
British thermal units in each pound of coal	10,197·79
Theoretical evaporation per pound of coal from and at 212° Fahr.	10·56
Efficiency of plant	74·14

The CHAIRMAN moved a vote of thanks to Mr. Sawyer for his paper, and the motion was approved.

Mr. WALTER DIXON (Glasgow) read the following paper, on the "Latest Developments and the Practical Application of Alternating Multiphase Machinery for Electric-Power Transmission":—

LATEST DEVELOPMENTS AND THE PRACTICAL APPLICATION OF ALTERNATING MULTIPHASE MACHINERY FOR ELECTRIC-POWER TRANSMISSION.

By WALTER DIXON.

During the past few years, great advances have been made in the application of electricity for motive-power purposes, and from the several important communications which have appeared in the *Transactions*, it is obvious that the mining industry has not been slow to take advantage of the many improved facilities and benefits in relation to mining engineering which have been thereby opened up.

In looking over these communications, they are readily divisible into two classes:—(*a*) Those of a strictly practical nature, giving results of the actual working of electrical installations already erected. (*b*) Communications dealing more or less with the theoretical side of electrical engineering, and with the special designing of electrical machines to meet the various requirements of mining work.

It is now generally admitted that while under certain known and definable conditions electricity is taking, and will continue to take precedence of methods hitherto employed, whether steam, compressed air, or hydraulic; it is also realized that in collieries exceptional conditions are encountered, and it is in view of these that the papers read and the discussions arising therefrom have a special importance.

A perusal of these past communications shows that when considering electrical machinery attention has centred round two or three points:—(1) The class of generator and motor to be employed, *i.e.*, whether series, shunt, or compound-wound machines; (2) the methods for obviating trouble and wear-and-tear in armatures, commutators, and brushes, in both generators and motors; and (3) the special designing of motors suitable for work in fiery mines.

With reference to the first of these points, it has been shown that where considerable starting-power is required a series-wound machine is preferable, though under varying loads the series-wound motor has the disadvantage of varying in speed according to the load; that shunt-wound motors are generally preferred where great starting-power is not essential, as they will maintain a fairly constant speed under a varying

load; and that the compound-wound motor will start under load and maintain a fairly constant speed, though for other reasons it is seldom employed. With regard to this head, therefore, it has been shown desirable to employ a special motor to suit the varying kinds of machinery to be operated.

Upon the second point, *i.e.*, the best method of construction of armature, commutator, and brushes, much discussion has centred, and though great improvements have of late years been effected, it is generally acknowledged by those who have experience of the working of electrical machinery, that it is here the chief troubles arise, and that while accidents are rare in other parts, the armature, with its commutator and connexions, is the source of probably 90 per cent. of the difficulties to be met with in electrical machinery.

With regard to the third head, viz., the suitability and adaptability of motors for fiery mines, various devices have been described in the *Transactions*, all of which, however, have been pronounced by one critic as "more or less a dangerous delusion and a snare."

These are the main questions which have hitherto called for the special attention of those concerned with the applications of electricity for mining purposes, and constitute the troublesome points which have been considered inevitable to the system, causing many colliery-proprietors to hesitate before stepping out of a track with which they are thoroughly conversant, into one which has apparent drawbacks.

It is in some respects a matter of surprise that little mention has hitherto been made of multiphase electrical machinery, a type of plant which is entirely clear of these various troubles and difficulties, possessing every advantage of the continuous-current or older type of machine, with the addition of other merits of primary importance.

The fact that the details of this type of machinery have been worked out and perfected abroad, probably accounts in a great measure for the fact that so little is here known about it, but it is hardly consistent with our national character that we should much longer continue to use a class of machinery, which for years has been largely superseded in those countries that are now in the van of electrical progress.

While we have been experimenting with small plants, we find in other countries installations of from 500 to 5,000 horse-power of multiphase machinery, many of which work without intermission from year's end to year's end, and are quite free from the uncertainties and difficulties which have been more or less associated with our experience of electrical power machinery.

The writer has, during some months recently spent on the Continent, examined in detail some 40,000 to 50,000 horse-power of electric plant on the multiphase system. It is with some degree of pleasure, therefore, that he is able to break ground which he believes will be more or less new to many of the members, and to further confirm his remarks, by conducting such as are sufficiently interested over the first works in Great Britain run on this system, and which, since its erection, has given most satisfactory results.*

It is not proposed in this paper to deal with the subject in a theoretical way, but to bring out a few of the points in connexion with

FIG. 1.—100 TO 500 HORSE-POWER, BELT OR ROPE-DRIVEN, MULTIPHASE GENERATOR, WITH ROTATING ARMATURE.

the practical working of this machinery, which, in view of past discussions, appear to specially mark it out as worthy of the attention of those interested in electric mining machinery.

The general appearance of the generator will be seen in Fig. 1, which represents a type of machine with rotating magnets. The outer iron casing enclosing the electrical parts is a distinctive feature, and it will be noticed that there is an absence of exposed conductors and connexions. Generators are built for any voltage, usually from 100 to 500 volts for short distances, and 500 to 10,000 volts for transmission over

* *Trans. Fed. Inst.*, vol. xiv., page 349.

long distances. Similar considerations regulate the voltage as in continuous-current machines—with the difference that while in the continuous-current system 600 or 700 volts has hitherto been considered the ordinary limit, this may be readily and almost indefinitely increased in the multiphase system—owing to the mode of construction and the readiness and efficiency with which the high-tension currents can be transformed.

It is a matter of special importance in this machinery that the conductors carrying high-tension currents do not revolve but remain stationary, and there is, therefore, every facility for securing and maintaining both electrically and mechanically a perfect insulation. Thus, with a generator giving off an electromotive-force of 10,000 volts, the current in the moving parts, *i.e.*, exciter, magnets, and collector-rings, need not exceed 100 volts. The generators which the members will see at work, have an exciting current of 65 volts.*

This consideration is of importance where long distances are concerned, and where, for the sake of economy in the conductors, it would be desirable to employ high voltages, and the practice is quite customary on the Continent, where the writer has seen numerous such installations, amongst others, one of 800 horse-power, in which the current is generated at 13,000 volts, and after being carried over a distance of 13 miles is reduced in the works to a low voltage by means of stationary transformers having an efficiency of 97 per cent.

FIG. 2.—5 HORSE-POWER MULTIPHASE MOTOR.

The benefit of this is readily appreciated by those who have to deal with long distances, or with machines where the motors are being constantly handled, and the risk of obtaining a shock is great.

Two different kinds of motors are shown in Figs. 2 and 3. The one of smaller size is used for powers below 10 horse-power and the larger

* *Trans. Fed. Inst.*, vol. xiv., page 349.

one from 10 horse-power upwards. The smaller type are generally arranged to work with fast-and-loose pulleys, or otherwise to start without load, and are switched in direct without the intervention of any intermediate resistance. The starting current is from two to three times the full working current. It will be observed that the stator or stationary part is compactly wound and completely protected from injury by the iron casing surrounding it, while the rotor or revolving part is of extremely solid form and without any outside connexions—at once the acme of simplicity and strength. The larger motors are generally

FIG. 3.—90 HORSE-POWER MULTIPHASE MOTOR.

similar in appearance to the smaller type, but have brass slip-rings fixed upon the end of the shaft for use in connexion with the starting resistance. It must not be supposed that these rings are in any sense of the nature of the continuous-current commutator, for they are made up of one solid casting, are subject to practically no wear-and-tear, and cause no sparking.

These motors can be arranged to run at varying speeds, and can be readily started under full load with a current not exceeding that of their

normal full working-load, and amongst their other merits may be mentioned the following:—(*a*) They are readily reversible. (*b*) The variation in speed between no load and full load does not exceed about 3 to 4 per cent., and the maximum speed for which the motors are built cannot under any conditions be exceeded (Fig. 4). No variation in the load, however excessive, calls for attention at the motors. (*c*) The motors are extremely efficient from about one-quarter to full load, and they can be built to work at their greatest efficiency at any particular load. (*d*) Owing to their general type of construction they can be fixed in any desired position on floors, ceilings, or walls (Fig. 5). (*e*) They will run for long periods without attention in extremely dirty and dusty places. And (*f*) lighting can be combined with power plants.

This class of motor also possesses what is perhaps of paramount importance in mining work, viz.:—Extreme simplicity of construction and mechanical and electrical strength in the vital parts, securing immunity from breakdown.

It has been stated that probably the only point in which an electric motor compares unfavourably with steam and other types is, that in the latter case the machine stops when excessively overloaded, whereas a continuous-current motor tends to destroy itself.

Those members who have had occasion to use electric machines for underground haulage where the sets of tubs occasionally get off the road, or for electric coal-cutting where a fall of coal instantly stops the machine, know that the motor will not stand such treatment with impunity, and that excessive sparking is not the end of the troubles occasioned thereby. But multiphase motors, while they will readily stand a reasonable amount of overloading, will, when excessively overloaded, come to a stand without injury to the machine.

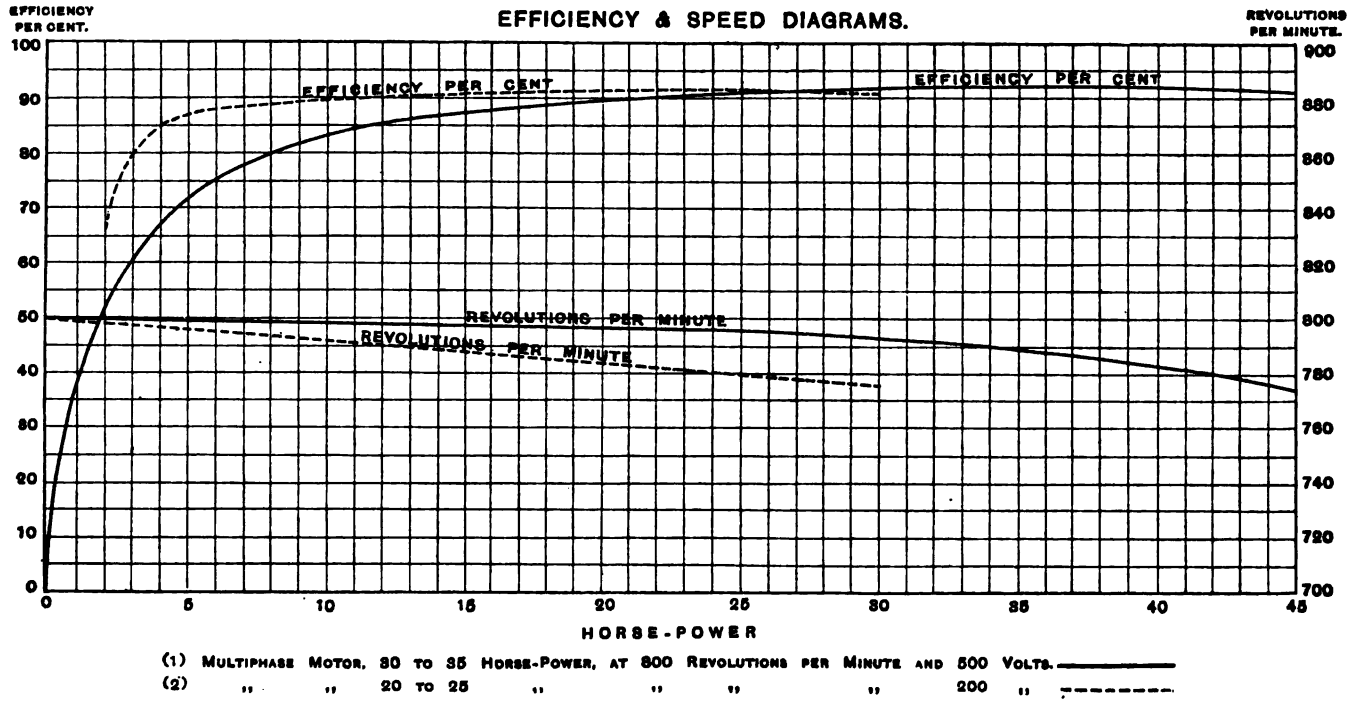
With regard, generally, to the question of efficiencies, the following results are obtained:—

	Full Load. Per Cent.	Half Load. Per Cent.
Efficiency of generators, at full load (depending on size)	90 to 94	85 to 90
,, of small motors up to, say, 10 horse-power ...	85	78
,, of large motors up to, say, 50 horse-power ...	92	88

It will undoubtedly not be long before many important installations are erected in this country, when the advantages which have been here described will become more widely known and appreciated, and the author is sure that the mining industries will not fail to take their due share of these improved facilities.

So far, the writer has had more particularly in his mind the applica-

FIG. 4.


EFFICIENCY & SPEED DIAGRAMS.
EFFICIENCY PER CENT.
REVOLUTIONS PER MINUTE.
100
90
80
70
60
50
40
30
20
10
0
900
880
860
840
820
800
780
760
740
720
700
EFFICIENCY PER CENT
EFFICIENCY PER CENT
REVOLUTIONS PER MINUTE
REVOLUTIONS PER MINUTE
0
5
10
15
20
25
30
35
40
45
HORSE-POWER
(1) MULTIPHASE MOTOR, 30 TO 35 HORSE-POWER, AT 800 REVOLUTIONS PER MINUTE AND 500 VOLTS.
(2) " " 20 TO 25 " " " " " 200 "

tion to private and individual installations. In view, however, of the fact that many of the important waterfalls of the world are being utilized for the generation of power for transmission over a distance, the question arises as to how far it would be economical to develop power at the reservoirs we possess in the form of coal-fields, and transmit the same to manufacturing centres, rather than handle and carry the coal, as is done at the present time.

FIG. 5.—SUSPENDED MULTIPHASE MOTOR.

We understand that in close proximity to the Niagara Falls, the company are prepared to sell power for continuous night-and-day loads at the rate of £3 12s. per annum per horse-power, and calculations have been made in which it has been shown that, under certain conditions as to load, the company can afford to distribute power within a radius of 200 miles at a less cost than it can be generated by users with the highest class of steam-engines anywhere within that radius, with fuel at 12s. per ton; and in the case of small loads amounting to, say, 500 horse-power, they could distribute power within a radius of 50 miles, and compete under the same conditions.

Also bearing on this point is the question as to how far it would be practical and economical, in districts like our own, to generate power at one particular centre for distribution electrically to the various collieries on the same field, thus saving the erection of numerous individual steam-plants with their necessary attendants. The writer is aware that much of the necessary steam-power is generated from fuel considered more or less unsaleable, but the advantages of such a system will become more marked with the increased gasifying of fuel, and the direct use of low-grade and producer-gas in gas-engines; for we may expect at no distant date to use gas-engines of much larger power than those to which we have hitherto been accustomed, capable of working with about half the coal consumption of our best modern steam-engines.

When these and other developments have familiarized engineers with the use and facilities obtainable from electric power-transmission, not only over small but large areas, the writer ventures to think that, unless some newer and more improved system is discovered, alternating multiphase machinery will from its simplicity, strength, and reliability, prove itself to be the most suitable, and thus far to have warranted its use in all the most important installations erected during the past few years.

Mr. Horace Allen (London) wrote that he noticed, with pleasure, that Mr. Dixon emphasized the advantages of the employment of gas-engines, driven with producer-gas, and that he approved of Mr. B. H. Thwaite's project of centralizing the power-generating plant near the collieries.* It will be instructive, in this connexion, to know that a recent test made by himself with a Thwaite coal-and-coke gas-power plant of some 300 indicated horse-power, and an Otto type of gas-engine, gave an average piston-pressure of 80 lbs. per square inch, with a consumption of 1 lb. of common coke, and without the employment of any steam-boiler, or any pressure whatever, beyond a few inches of water. This plant is much lower in first cost than a high-class steam-boiler plant, and the simplicity of the entire system delighted all who had seen it. With reference to the southern coal-field in the Transvaal, there is a scheme on foot for the installation of a central gas-power and electric-generating station in the coal-field to supply electric power by the alternating system to the Rand gold-mines.

* *Nineteenth Century*, December, 1894, page 919.

Recently, he had made further tests of the gas-plant and engine above mentioned. The gas-generators were tested in three different ways :—(1) with coke only, (2) with coke and slack coal, in which cases water was admitted to the hearth, and (3) with coke and dry air. The analyses of the gases and power produced in each trial were as follows:—

Analyses of Gases, &c.	Percentage Composition by Volume.		
	Water in Hearth.		Coke, with Dry Air.
	Coke only.	Coke and Coal Slack.	
Carbon dioxide, CO_2	2·8	3·8	3·4
Carbon monoxide, CO	28·2	26·1	26·0
Hydrogen, H	4·1	6·6	1·8
Marsh gas, CH_4	1·8	1·8	3·1
Nitrogen, N	63·1	61·7	65·7
Totals	100·0	100·0	100·0
Thermal value of gas at 32° Fahr. down to 212° Fahr. per cubic foot, in British thermal units	124·8	125	123
Mean pressure in pounds per square inch...	77·5	88	71·2
Indicated horse-power	113	150	101
Cubic feet of gas used per indicated horse-power per hour	87	—	98

The engine had two cylinders each 16 inches in diameter and 24 inches stroke, and was run at 140 revolutions per minute. The efficiency of the gas-generating plant was 90 per cent., and the quantity of heat turned into work by the gas-engine equalled 22·8 per cent.

Mr. R. Holiday (Pontefract) remarked that, as at Acton Hall colliery, Pontefract, they had 540 horse-power (electrical) this subject was interesting to him, and there were one or two remarks he should like to make. He thought that Mr. Dixon was rather hard on the *Transactions* when he said that hardly any mention was made of the multiphase-system. The reason mining engineers, until recently, had not taken up the use of the multiphase-system of driving was owing to there being no manufacturer in Great Britain, and if anything went wrong with it in the mines they would have to send it to the Continent for repair. There was also the fact that three wires were required, and the maintenance of the cables along the roads was one of the most serious matters in connexion with the use of electrical machinery in mines. The disadvantage of the extra wire was, however, far more than made up by the fact that there was no sparking, and by the improved efficiency of the machinery. For those who had continuous-current electrical plant

in use, he thought that it would be encouraging to be told that it was possible for the continuous-current generator, with a slight alteration, to produce an alternating current.

Mr. JAMES MALCOLM (Arniston) asked whether Mr. Dixon would propose to place his transformer at the surface or where the actual work was done. He considered, although multiphase-machinery was efficient, that continuous-current motors were best adapted for use in mines.

Mr. G. E. SMITH (Nottingham) asked whether the armature became heated when there was an overload on the motor.

Mr. G. A. MITCHELL (Glasgow) said that there was less liability of accidents in the multiphase-motor than in a motor on the direct-current system. That was of great moment, especially in connexion with coal-cutting, and it was certainly a great advantage that there should be no breakdown through material overloading. It was impossible at times to prevent excessive overloading, and in the direct-current system serious damage necessarily occurred. Reference had been made to the fact that three cables were used instead of two. However, the cables would be smaller, and therefore possibly the expense would not be so very much greater than in the other case. He asked whether there was sparking at the transformers, and whether it would not be dangerous to place transformers in a mine where there was risk of explosions by fire-damp. He would like Mr. Dixon to advise the members with reference to the danger of shocks. Were shocks from an alternating current more dangerous than shocks from direct current? He thought that multiphase motors were well worthy of careful examination, more especially as in the United States they seemed for long distances to be putting aside direct current in favour of the multiphase system.

Mr. G. S. CORLETT (Wigan) agreed with Mr. Dixon that the three-phase system of machinery would be largely adopted in mining work. The reason why British electrical engineers had not up to the present time used multiphase machinery for mining work was the impossibility of obtaining until recently a three-phase motor in which the speed could be closely controlled. In continuous-current machinery, the regulation of the speed of the motor was extremely simple, and by the use of a suitable resistance one could obtain any possible variation in speed desired. He did not agree with Mr. Dixon's statement that 90 per cent. of the troubles in using electrical machinery in a mine were due to the commutator, armature, and connexions. The motor was only one part of the plant, and in addition there

were switch-gear and connecting cables, and in mines where there was considerable liability to falls of roof and sides, he found that the maintenance of the cables was a much more serious matter than the maintenance of the armatures, etc. Any ordinary well-constructed motor working under normal conditions would not spark, and it was, he thought, absolutely impossible to fire gas from an ordinary open-running motor with properly trimmed brushes and a smooth commutator. To obviate the danger arising from carelessness on the part of the attendant, a very large number of continuous-current motors had been constructed, in which the whole of the motor was enclosed in steel-castings, and there was not the slightest danger of explosion so long as the attendant did not forget to close the doors. He had, in his experience, found frequent cases where the electric motor for short periods had been overloaded to at least double its normal load. In such cases there was not excessive sparking at the commutator of an ordinary continuous-current motor, and if the work went considerably above the half load the safety-fuse (which should be placed in some convenient position) would blow. With the three-phase system, the motor would stop, and the excessive current would pass through and blow the fuse. The point was, that the continuous-current motor would stand overloading with very much greater impunity than would the three-phase motor. Mr. Dixon stated that with continuous-current generators, from 600 to 700 volts was about the maximum pressure, but that was incorrect. All the original arc-lighting in this country was effected with high-tension continuous-current machines working up to 2,000 volts and upwards, and in a very large electrical plant erected in Australia a few years ago, a pressure of 3,000 volts was employed. For heavy pumping, coal-cutting, and haulage, where they needed a large starting force, the continuous-current motor was the most efficient. There was one advantage of the three-phase system (which Mr. Dixon had not touched upon), and that was the possibility of dealing with all the machinery that was ever likely to be required at a colliery at a pressure of 400 to 500 volts in an economical manner without excessive cost of conductors. It was possible to make, in the three-phase system, a connexion from what he termed the middle wire, so that while between any two of the three wires from the generator they had the full pressure of 400 volts, between the neutral wire and the others they had a pressure of about 240 volts. It was practical to obtain incandescent lamps which burned at a pressure of 240 volts, so that the lighting could be divided up into three main circuits, one between each phase wire and the neutral wire; and the incandescent lamps would be run in single parallel, and

the motors used without the addition of transformers, or excessively large conductors, and without introducing unnecessary complication into the system. Such an arrangement avoided the use of two separate plants and the inconvenience of running the lamps in sets of two in series, but there was a trifling disadvantage, viz., that it was more difficult to run arc-lamps from a three-phase system. The best thanks of the members were due to Mr. Dixon for bringing before them so interesting a subject which, in his opinion, was bound to claim the attention of all mining engineers.

Mr. WALTER DIXON, in replying, said that his paper had not been written in any sense in antagonism to the continuous-current system, but with the idea of bringing before the members a system which, by its various merits and advantages, had already in other countries almost superseded the continuous-current system, and which he felt was destined to do the same in this country. Mr. Corlett had made certain statements as to what the continuous-current system could do in mining work. From the theoretical side, he agreed with these claims, but his experience had led to a somewhat less favourable view when it came to actual work in the mine. He was aware that continuous-current machines were built to run at high voltages, but he was not aware that the figures mentioned by him, *i.e.*, 600 to 700 volts, had been exceeded in pit work in Britain. He believed that 500 volts was the limit in Scotland, and 350 to 400 volts was more common. If, however, it was a question of using high-voltage motors, then the advantages which he had pointed out, both as regards strength, simplicity, and reliability, left no question as to immense advantages being obtained in the multiphase motor. He was sure Mr. Corlett would be glad to know that the difficulties of speed regulation had been overcome, and that it was now possible to obtain the same regulation in multiphase motors as it was with continuous-current. There might or might not be a disadvantage in the fact that three were required instead of two conductors. Any disadvantage, however, was somewhat mitigated by the fact that the three cables were not so large as when two were used. He might state that the costs of the machines and the cables were approximately the same as for continuous-current plant. Shocks from an alternating current were more severe than from a continuous current, and was generally reckoned so in the proportion of $1\frac{1}{2}$ to 1, *i.e.*, a shock from an alternating current at 400 volts was considered equal to that from a continuous current at 600 volts. With regard to the starting of multiphase motors under load, he could only repeat what he had already stated, that

they can "be readily started under full load with a current not exceeding that of their normal full working load."

He had mentioned that his first acquaintance with the multiphase system was so favourable that he felt sceptical, but subsequent visits to numerous large installations on the Continent, however, only confirmed the results of his first visit. Since that time, he had had the honour to be the first to introduce multiphase machinery into Great Britain, and the installation which the members would visit was the first of several so introduced.* After about two years' working, they were still looking for the the proverbial "fly in the ointment," but it had not yet made its appearance; and it was clear to him, as he felt it must be to everyone who had any practical experience of this system, that in supplanting the continuous-current by the multiphase system, it amounted to superseding what was a more or less complex system, which required to be carefully and skilfully handled, with a much simpler one, possessing rigidity, strength, and simplicity, together with many other qualities essential in an electric-motor plant for mining work. He was not aware of any merits in continuous-current machinery that were not present in the multiphase system, and he was therefore at a loss to understand under what conditions continuous-current motors were best adapted or even equally adapted for use in mines.

The CHAIRMAN said that the applications of electricity had been developed much more largely on the Continent than in Great Britain. Papers on electricity, he thought, must interest the members; they were indebted to Mr. Dixon for bringing the matter before them, and he had pleasure in moving that a vote of thanks be accorded to Mr. Dixon for his paper.

The motion was agreed to.

Mr. G. A. MITCHELL moved, and Prof. H. LOUIS seconded, a vote of thanks to the Mining Institute of Scotland, who had made the arrangements for that meeting, and to the owners of collieries and works opened to the inspection of the members.

The motion was agreed to.

Mr. M. H. MILLS (Nottingham) moved a vote of thanks to Sir Lindsay Wood, for his services as President during his year of office, and for presiding over that day's meeting. The members must also, at the same time, congratulate him on the honour that he had received from Her Majesty.

* *Trans. Fed. Inst.*, vol. xiv., page 349.

Mr. J. S. JEANS (London), in seconding the motion, remarked that Sir Lindsay Wood had well deserved the honour which had been conferred upon him by Her Majesty.

The CHAIRMAN thanked the members for the vote of thanks which they had given him. It had afforded him very great pleasure to have occupied the position of President of their Institution during the past year. He was satisfied that the Institution was doing a vast amount of work and a great deal of good throughout the whole of the mining world. He hoped it would go on and prosper as it had done during the past few years.

The meeting was then closed.

The following notes record some of the features of interest seen by visitors to collieries and works, which were, by kind permission of the owners, opened for inspection during the course of the meeting on September 14th, 15th, and 16th, 1897 :—

NEWBATTLE COLLIERY, LADY VICTORIA PIT.

The minerals leased to the Lothian Coal Company, Limited, extend over 15,000 acres, and a very large proportion of this area can be worked in connexion with the Lady Victoria Pit. The shaft is circular, and lined with brick from top to bottom. It is 20 feet in diameter, and descends to a depth of 1,656 feet. Four years were occupied in the sinking, and it is noteworthy to recall that by means of a movable steel scaffold suspended on wire ropes, the masons' work of lining the walls with bricks went on simultaneously with the excavations of the pit-sinkers below.* At the bottom of the shaft, siding accommodation is provided for dealing with a large output of coal.

The approach to the workings consists of an arched tunnel lined throughout with brickwork. It ranges in height from 35 to 15 feet, and the roads to the various coal-seams branch off this main tunnel. These seams comprise the Jewel coal-seam, which yields household and cannel coal; the Splint seam, a steam coal; the Coronation and the Diamond seams, both household coal; and the Great seam, a steam coal similar to the Splint.

Flooding is prevented by a triple-expansion pumping-engine, placed at a depth of 800 feet, and throwing the whole of the water from that point to the surface; while the lower feeders are dealt with by electric pumps

* *Trans. Fed. Inst.*, vol. viii., page 118.

situated at a depth of about 1,400 feet from the surface. The power necessary for driving these pumps is generated by dynamos on the surface driven by steam-engines of the Corliss type, and the electric current is conveyed to the pumps underground by insulated copper cables. A small proportion of the electric current is also utilized for lighting the bottom of the shaft, pumping-stations, and other important points underground.

The pit is ventilated in connexion with the neighbouring Lingerwood mine by means of a Guibal fan 30 feet in diameter, producing 100,000 cubic feet of air per minute at 0·75 inch of water-gauge, at a speed of 50 revolutions per minute.

The haulage of the coal to the pit-bottom is effected principally by means of engines driven by compressed air.

There are two double-decked cages in the shaft for conveying the minerals to the surface. Each of these is capable of carrying twelve hutches of coal, equal to 6 tons, or of ascending or descending with 48 men. The cages are kept in position in the shaft by wire-rope guides, and a wire cable, attached to the bottom of each cage and hanging in a loop down the shaft, supplies a compensating balance to the deadweight of the winding-ropes. In this way, and with the weight of one cage and its hutches balancing that of the other cage and its hutches, the net load which the engine has to raise to the surface is the 6 tons of coal in the full hutches. Both at the bottom and at the top of the shaft, arrangements are made for loading and discharging the two decks of the hutches simultaneously, so that time is saved and wear-and-tear of plant modified. The pulley-frame over which the winding-gear is carried is a massive structure of steel, 85 feet high, and the winding wheels are each 19 feet in diameter.

The whole of the overhead machinery and works are enclosed in substantial brick structures, with steel columns, joisting, and roof-supports, and galvanized roofing.

The winding-engine of 2,400 horse-power is of the most approved type, with two steam-jacketed cylinders each 40 inches in diameter by 7 feet stroke, fitted with automatic expansion-gear operating on Cornish double-beat valves. The drum is 21 feet in diameter, and the engine is controlled in case of emergency by two steam-brakes acting upon the rims of the drum, either automatically or by direction of the engineman.

Steam is supplied by six Lancashire boilers, 8 feet in diameter and 30 feet in length, working at a pressure of 100 pounds to the square inch, and these boilers are fed with heated water from economizers.

Over the pithead, there is a floor-space covering about ½ acre, upon which, and having a slight downward gradient from the pit, 6 hutch-tracks branch off from a main line leading from the landing-stage above the shaft, and communicate with tippers. Let one of the hutches containing coal be followed in its progress from the shaft-cage. Pushed on the rails by one of the men, it runs along the main track, until by a catch on a travelling-chain between the rails, it is brought to a momentary stand on a weighing-machine in front of the weigher's desk. Having been weighed and credited to the miner whose number it bears, it presently passes on, and approaches the points-boy, who, quick to note its contents, moves this lever or that, and shunts it into the line leading to the tipper destined for the time being to receive it. A man in charge of the tipper pulls a lever, and forthwith the hutch is turned upside down; and, emptying its contents into the shoot, returns to its original position. Lightened of its burden, it is pushed from the tipper, and then it runs by gravitation to a point whence, caught by an endless-chain, it returns, by an elevated circular route, to the top of the shaft. The coal, after being emptied from the hutch by the tipper into the shoot, falls upon an endless steel-band 4 feet wide, travelling at a slow speed. From this it is dropped upon a shaking-screen, the bottom of which is perforated, admitting of the smaller coal passing through. From the shaking-screen, the large coal is delivered upon another endless steel-band 35 feet long and 4 feet wide, travelling at double the speed of the former band. The coal falls upon the second band in a thinly distributed stream, and any impurities are readily detected and removed by men stationed at intervals along the band. The small coal passing through the perforators of the shaking-screens is taken by an endless conveyer to the washing-station, where it is freed from dirt and impurities, and then subdivided into six different sizes to suit market requirements.

The area covered by the works and railway-sidings is 40 acres, the latter comprising about 3 miles of lines.

BROXBURN OIL COMPANY, LIMITED.

The works and mines now cover upwards of 250 acres, and give employment to about 1,700 workpeople, of whom one-half are employed in the mines. About 1,400 tons of oil-shale are put through the retorts daily, and about 13,500,000 gallons of crude oil are refined per annum. The consumption of coal is about 400 tons per day.

The Broxburn works comprise crude oil-works, sulphate-house, refinery, acid-works, candle manufactory, and cooperage. The Roman Camp crude oil-works are connected with the refinery by a short line of railway.

The mineral field has an area of about 4,000 acres, and is mined in the same manner as coal. The field is in the form of an inverted basin, the crude oil-works being placed in the centre, with mines radiating therefrom and pits sunk to the deeper parts of the shale-seams for the drainage of the workings.

The hutches on reaching the surface are emptied into railway-waggons, and conveyed to the hydraulic tippers, and the shale shot into the hoppers leading to the breaker. The shale, broken into cubes of about 3 inches, is then fed into hutches, carrying about 12 cwts. each, and conveyed by a cable-line to the platform at the top of the various benches of retorts. The hutches are discharged into iron hoppers holding about 18 hours' supply of shale, which is mechanically fed into the retorts placed beneath.

There are 500 Henderson vertical retorts in use at the Broxburn works, and 240 of these retorts at the Roman Camp works, or 740 retorts in all. The retorts are about 28 feet long, the upper portion being of cast-iron (about 11 feet long) and the lower portion of brick. The oil is distilled from the shale in the cast-iron part, at a temperature of about 900° Fahr., and the spent shale is passed downwards into the brickwork portion of the retort, which is kept at a temperature of about 1,300° Fahr. This high temperature increases the yield of ammonia and permanent gases from the carbon of the shale. The products of distillation in the form of vapour are withdrawn at the top of the retorts by a branch pipe. In passing downward through the retort, the shale is kept in constant motion by means of a toothed roller inserted at the bottom, which delivers the spent shale into a hopper. The retorts are heated by gas generated in gas-producers and introduced by ports at the sides. The incondensable gases from the shale-distillation are mixed with the producer-gas to assist in heating the retorts.

The Broxburn shale yields 32 gallons of crude oil and 44 pounds of sulphate of ammonia per ton; while the Drumshoreland shale yields 20 gallons of crude oil and about 70 pounds of sulphate of ammonia per ton.

The products of distillation, in the forms of oil and watery vapours, and the permanent gases, on leaving the top of the retorts, pass into a large main towards an air-condenser (consisting of a series of vertical pipes),

where they become condensed into crude oil and ammonia-water. The liquids flow into a small separator-tank, and a pipe fitted close to the bottom draws off the ammonia-water, while another pipe fitted near the top of the tank draws off the crude oil, each into its own receptacle. The incondensable or permanent gases are used as fuel.

The spent shale is stored in large rubbish bings.

In the manufacture of sulphate of ammonia, the ammonia-water is passed into a column-still, provided with a series of horizontal trays. The water is admitted at the top, and flows from tray to tray until it is discharged at the bottom of the still, where steam is introduced at a pressure of about 50 pounds per square inch. This steam escapes at the top of the still, carrying with it the ammonia-gas and bubbles through holes in a series of leaden pipes at the bottom of the saturator-tank containing sulphuric acid, and forms sulphate of ammonia. The steam, carbon dioxide, and sulphuretted hydrogen are conveyed from the saturator-tank to the retorts. The sulphate of ammonia is lifted out of the saturator-tank as it is formed, by means of perforated ladles. The salt is drained for about 12 hours, and is then wheeled into the store-house, where it is passed through a crushing-mill and placed in bags.

The crude oil is pumped to the refinery into a tank containing about 50,000 gallons. It is afterwards pumped into charging-tanks, from which it flows, by gravity, to a set of crude-oil stills, coupled together by pipes, and worked on the Henderson continuous system. The first distillation of the crude oil yields green naphtha, green oil, and still coke (a valuable smokeless fuel). The green naphtha is treated with sulphuric acid and caustic soda, and, after distillation by steam, yields shale-spirit or naphtha with a specific gravity ranging from 0·725 to 0·740. The green oil is also treated with sulphuric acid and caustic soda, and is then ready for the second distillation. In these treatments, the oil is stirred with sulphuric acid and allowed to settle, when a black tar falls to the bottom of the tank and is run off; while the oil is run from the upper to the lower washer, where it is mixed with a solution of caustic soda, and on settling another black tar separates. From these tars, the sulphuric acid is removed and is used in the manufacture of sulphate of ammonia; the residual tars are injected by steam jets into the still-furnaces in the form of fine spray, and burned as a fuel.

In the second distillation, the green oil is fractionated into light and heavy oils—the latter containing solid paraffin. The light oils are treated and distilled several times for the following brands of burning oils :—

	Specific Gravity.	Flashing-point. Degs. Fahr.
Petroline	0·800	110 to 120
No. 1 paraffin oil...	0·806	120
Lighthouse oil	0·810	150
Marine sperm	0·830	230

To obtain the solid paraffin from the heavy oil, it is cooled down below 32° Fahr., and the paraffin strained out by means of filter-presses, the products being blue oil and crude solid paraffin. The blue oil is treated, distilled, and fractionated into intermediate oils (used for gas-making and other purposes), and heavy oils used for lubricating machinery. The crude solid paraffin is passed to the sweating-house, where it is fractionated and refined by the Henderson process to a melting-point of 120° Fahr., and is known as semi-refined paraffin wax. The sweating and fractionating process is repeated to produce refined paraffin wax with a melting point between 125° to 130° Fahr.

After the sweating process, the liquid paraffin is mixed with char, settled, and then filtered through paper. It is then cooled into blocks of paraffin wax, ready for making into candles, night-lights, wax matches, and other purposes. About 4,000 tons of refined paraffin wax is produced per annum, the greater part of which is made into candles before leaving the works.

The candle factory is capable of producing about 20 tons of candles per day, and is fully equipped with the most modern forms of packing-case nailing machinery.

The soft paraffin wax or match paraffin, with a melting point of about 100° Fahr., is used to cover the heads of wooden matches instead of sulphur. It is also used for burning in safety-lamps, etc.

The sulphuric-acid manufacturing plant is divided into two works, each consisting of 5 chambers, 2 Glover towers, and 1 Gay-Lussac tower, which, on one side, is connected with the chimney, and on the other with the centre chamber. There are also leaden pans and platinum stills for concentration capable of producing 14 tons of concentrated sulphuric acid, and 26 tons of 144° sulphuric acid per day.

The cooperage comprises a drying-shed for barrels; coopers' shop for repairing barrels; a glue-house, where the insides of the barrels are covered with a thin coating of glue, so as to close the seams and prevent the oil from escaping through the pores of the wood; a shop for painting the barrels; and the filling-house, fitted with the Crawford apparatus, which automatically shuts off the oil when the barrel is full.

NIDDRIE COLLIERIES.

The Niddrie collieries are situated about 4 miles south-east of Edinburgh, and the principal produce is cannel coal. The seams worked lie at an inclination varying from 50 to 70 degrees, the maximum depth of the workings being about 2,400 feet where the strata are beginning to flatten.*

The principal winding-and-pumping centre is at Nos. 8 and 12 inclines and No. 13 pit, which are situated close to each other. There are three stages of steam-pumps, each working with a head of over 600 feet. Steam is taken down the No. 8 incline, a distance of 3,100 feet, in pipes 10 inches and 6 inches in diameter.

The Moore hydraulic pump† is placed alongside of a Hathorn-Davey steam-pump on the second stage as a duplicate, and was started in December, 1896. The surface-machinery is erected at No. 13 pit, and consists of a compound condensing tandem engine. The high-pressure cylinder is 18 inches and the low-pressure cylinder 32 inches in diameter, running at forty revolutions per minute, and driving, by means of 6 to 1 gearing, four hydraulic pump-rams, each 8¼ inches in diameter. The distance from the surface-plant to the pumps in No. 12 mine is 2,525 feet. The hydraulic power is conveyed in four lines of malleable iron piping 4 inches in internal diameter and ⅜ inch in thickness. In the mine there are four pump-rams, each 11½ inches in diameter, driven by two hydraulic-power rams, each 5¼ inches in diameter. The head of water in the mine-pump is 660 feet: at seven strokes per minute the water discharged is 457 gallons, and the pressure on the power-pipes in the mine, at the pump when at work, is 1,792 pounds per square inch.

The result of a careful test shows that, when running at 36 revolutions per minute with a full load, the engine develops 125 horse-power, and when running with underground pumps empty, 37 horse-power was indicated. The plant thus gives over 70 per cent. of useful effect of the power expended. During this experiment, the engine was running with steam at 45 lbs. pressure, it being more convenient at present to work at the ordinary pressure of the range of boilers; but the engine is designed to work with steam at 90 lbs., and a more economical result will, no doubt, be obtained when that pressure is secured.

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* *Trans. Fed. Inst.*, vol. vi., page 388. † *Ibid.*, vol. iv., page 331.

MESSRS. REDPATH, BROWN & COMPANY, LIMITED, ST. ANDREW STEEL WORKS, EDINBURGH.

The business of steel girder, roof and bridge manufacturers, together with the manufacture of a water-tube boiler, is carried on at the St. Andrew Steel-works, which were erected in 1894 and are at the present time undergoing large extensions.

Apart from their general construction, the works are of especial interest inasmuch as they are the first works in Scotland to be wholly electric driven, and the first in Great Britain to be driven by multiphase electrical machinery.

The original and smaller installation was erected with the intention of supplementing it with a duplicate plant, but an altogether larger plant has, however, been found necessary. The plant consists of : (1) One 90 horse-power multiphase generator, having an electromotive-force of 200 volts., and running at 800 revolutions per minute. It is driven by a compound tandem engine, with cylinders 11¼ and 18½ inches in diameter by 24 inches stroke. The water-tube boiler works at a pressure of 200 pounds per square inch. (2) One multiphase generator of 30 horse-power, also running at 800 revolutions per minute, with an electromotive-force of 200 volts. It is driven by a gas engine worked from a Dowson gas-plant, in close proximity to the engine.

These two generators are arranged to run in parallel, and the switch-board is so arranged that any of the motors in the works can be run from either or both of the generators. This arrangement secures economy in driving. During night-shift work, when all the machinery is not required, the smaller generating plant is used.

The machinery in the works is driven by 11 motors, as follow :—A 20 horse-power motor operating a set of plate rolls ; a 15 horse-power motor operating a set of hydraulic pumps ; a 14 horse-power motor operating a large plate planing-machine, a boiler shell drilling-machine, and a punching and shearing machine ; a 10 horse-power motor operating a tube-hole cutter ; two 10 horse-power motors each operating a set of radial drills ; a 9 horse-power motor operating 2 cold saws, 1 punching and shearing machine, and 1 saw sharpener ; a 9 horse-power motor operating a pneumatic hammer fan for smithy blast, and a lift pump ; a 5 horse-power motor operating a set of 3 radial drills, 1 grindstone, and 1 cold saw ; a 5 horse-power motor operating a turning lathe ; and a 5 horse-power motor operating a set of 3 radial drills.

The electric lighting plant, consisting of arc and incandescent lamps, is also arranged to run in conjunction with the motors.

In many cases, the motors are fixed underground for convenience, the starting switch and resistance being fixed aboveground in convenient positions. By this arrangement, there is an absence of overhead shafts and belts, the spaces being kept clear for travelling cranes, etc. It has also obviated the necessity of heavy walls for carrying shafting, hangers, etc.

The works present a good example of a modern electric driven establishment, and the result, from a practical standpoint, has been economical working and absence from trouble or breakdown.

McLARTY BORING-MACHINE.

The McLarty boring-machine was experimentally erected at the Newbattle colliery. This is a method of rotary boring, the rods consisting of ordinary tubing, whilst the tool consists of a short length of a double-winged auger made of some special quality of steel and hardened in a manner which the inventor desires to keep secret, but which, he states, will produce an edge of such hardness as to cut through the hardest stone with little or no wear. The tube is revolved by means of a horizontal wheel, round which passes an endless chain driven by means of a windlass; weights can be applied to the upper part of the tube so as to produce any required pressure upon the cutting tool. Inside the tube, there is a small bucket elevator, on very much the same principle as the Chinese chain-pump; this elevator delivers at the top of the tube into a detachable receiver with a glass front, a pair of small revolving brushes, removing all fragments of borings from the elevator. As soon as the receiver is full, it can be instantly detached and another one substituted. The cutting tool is of such a shape that all the borings made are thrown inwards towards the elevator bucket. As depth is gained, an additional length of elevator chain can be added in a few minutes. The object of the invention is to produce a drill that shall deliver its borings whilst the process of boring is proceeding, and thus save the time lost in drawing the tools out of the borehole in most other methods. The machine was shown boring a block of sandstone at the surface, but there was no opportunity for judging how it would stand the rough work of putting down an actual borehole.

EDINBURGH NORTHERN CABLE TRAMWAYS.

The Trinity route meet Princes Street in Hanover Street, and proceeds north over the hill in George Street, and then descends Pitt Street, a steep incline. Passing Henderson Row, where the cables branch off to the engine-house, and after crossing the old Canonmills bridge, at the lowest part of the route, the line ascends easier grades to the Trinity terminus. The cable traverses 18 curves of radii varying from 80 to 980 feet. The total height ascended is 187 feet, and the track is 3 miles long.

The Stockbridge route also starts from Princes Street, and travels parallel and over almost identical grades, as the first portion of the Trinity route. After passing round 100 feet curves into the Royal Circus, the lines are almost entirely a series of curves passing through steep and narrow roads. At Stockbridge, the cable leaves for and returns from the engine house. The cable traverses 28 curves of radii varying from 80 to 400 feet. The total height ascended is 173 feet, and the track is 2·4 miles long.

The two routes are operated from the engine-house in Henderson Row, 400 feet from the Trinity route, and 1,650 feet from the Stockbridge route.

The cables used are of the very best patent improved crucible steel wire, Lang lay, laid round a hempen core, in 6 strands, each of 13 wires (7 round 6). The wires have a tensile strain of 80 tons per square inch. The lay of the rope is 9 inches, and the circumference is 3½ inches.

The track rails are of ordinary girder type, 6 inches deep, and weigh 75 pounds per yard.

The cable-tube is 9½ inches wide and 19 inches below the surface of the road. This tube is made of concrete, with embedded cast-iron tube frames. The recesses in the concrete are drained by a sanitary pipe, 6 inches in diameter. The cable-supporting pulleys, 14 inches in diameter, are placed 50 feet apart, the journals revolve in lignum vitæ bearings, with lubricating appliances, and run 3 months without attention. The pulleys for conducting the cable round curves, 14 inches in diameter, are spaced as required for varying conditions and radii; by the use of sleeves, the portion worn by the cable can be renewed when required.

The slot-rail, invented by Mr. W. N. Colam, reduces the depth of the tube to a minimum, and forms a support for a friction roller on the gripper when passing round curves. The slot-rails are made of steel, and weigh 39 pounds per yard.

The tram-cars are of the bogie type, fitted with powerful brakes, one acting on all eight wheels, and the other on the track-rails.

The grippers, invented by Mr. W. N. Colam, are suspended from the axle of the tram-car. The cable is held between two jaws, the upper one being fixed, and the bottom one can be lowered 6 inches, so as to pick up the cable, which ascends into its place in the gripper as soon as the rounded bottom of the jaw touches it. The cable is gripped by soft iron dies, which last about 6 weeks. There are two rollers fixed on each side of and above the gripper, one of which revolves on the recess in the slot-rail on going round curves, and takes the torsional strain close to where it is created by the cable.

The two driving engines have horizontal cylinders, 20 inches in diameter and 40 inches stroke, fitted with Proell automatic expansion valve-gear, which is effective in controlling the varying conditions of traffic, and requires very little attention. The V driving-pulley is $10\frac{1}{2}$ feet in diameter, around which there is only a three-quarter lap of the cable. The jaw of the pulley is removable in segments and is lined with white metal, which can be easily replaced when worn. The tread of the pulley is filled with soft wood.

The cost of equipping these lines for a 3 minutes' service of cars was £75,000, including all expenses in and out of Parliament.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
DECEMBER 13TH, 1897.

MR. JOEL SETTLE, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBER—

Mr. J. LEITCH PARKER, Mining Engineer, c/o Messrs. Dabnay and Parker, Mining Engineers, Rossland, British Columbia.

ASSOCIATE—

Mr. FREDERICK WILLIAMS, Under Manager, Berry Hill Collieries, Stoke-upon-Trent.

Mr. E. B. WAIN read the following paper on "The Workmen's Compensation Act, 1897" :—

THE WORKMEN'S COMPENSATION ACT, 1897.

By EDWARD B. WAIN.

Since last discussed, the principle of the Workmen's Compensation Bill had been accepted by Parliament, and had now passed into law. It is, therefore, for the present useless to consider whether the principle is a good one or not; and, as we cannot hope for any modification or alteration for some time to come, we are bound to take the Act as it stands. In passing through its various stages, the Bill was somewhat modified, and a few small additions made, safeguarding the employers' interests to a slight extent; but we still have to accept the fact that from July 1st next practically all accidents met with by colliery workmen will render the employers liable to pay compensation on a liberal scale, whether due to any defect in plant, to negligence of those in authority, or whether the accidents are, in the full sense of the word, unavoidable and arising from circumstances over which no one can have the smallest control.

The Act does not in any way supersede the existing law as to employers' liability, but the employer cannot be called upon to pay compensation both independently of and under the new Workmen's Compensation Act.

The writer does not propose to enter into the question of the cost of working the Act as applied to mining, that being a question more particularly for the consideration of colliery owners, but he thinks that the attention of this Institute, which is so largely composed of men who are placed in positions of authority and supervision, and who will be responsible to the owners for the working of the Act, may with advantage be given to consideration of a few points in connexion with the administration of the Act as applied to their particular industry.

In discussing the question he ventures to repeat an assertion made at a former meeting, that, in his opinion, no part of the increased safety to life and limb which has marked the progress of mining operations for the past 20 years has been due to the working of the Employers' Liability Act, and that the same care in working would have been exercised by colliery owners and officials if that Act had never been

passed; in a word, that they have not, in this matter at least, been governed by mercenary motives, and that they have endeavoured to secure greater safety from a genuine interest in the welfare of their workmen.

Now, however, the Government of this country have placed a high premium on personal injury, and it is much to be feared that the unremitting care and devotion that members of this and kindred institutions have given to promote the safety of the miners will be to some extent counteracted by greater indifference and recklessness on the part of the workmen.

In order to guard against so deplorable a contingency, it will be more than ever necessary that the strictest supervision should be exercised; that the powers placed in our hands to enforce the General and Special Rules drawn up for the safety of the men should be justly but firmly enforced; and that whilst on the one hand they learn that the law gives them compensation for accident, on the other hand they should be taught that the penalties of the law await all those who wilfully and deliberately neglect to obey the rules which have been so carefully drawn up with a view to prevent accidents.

Turning to the Act itself, there are many points which we can with advantage discuss, and amongst the most important is that raised in the opening words of the first section, which speaks of "personal injury arising out of or in the course of employment."

And here we are reminded that it will be necessary to see that the next provision, section 2 (1), which states very definitely that proceedings to recover compensation shall not be maintainable unless notice is given "as soon as practicable after the happening" of the injury, is duly enforced.

It follows, therefore, that any alleged accident must be immediately enquired into, and all the circumstances carefully recorded, if we are to carry out the Act properly in the interest of the owners and prevent imposition.

This will be a great safeguard; and further protection is given in section 3 of the first schedule, which provides that the workman claiming compensation must, when required, submit himself to an examination by a qualified medical man appointed by the owner.

If these two courses—(*a*) careful investigation of the site and circumstances of every alleged accident, and (*b*) medical examination of the injured person by an independent medical man—are followed in every case the possibilities of imposition will be reduced to a minimum. But

it seems prudent to go further than this, and to obtain, if possible, some assurance that each workman is physically in a fit condition before he is employed.

If any person desires to take out a policy to obtain certain payments from an insurance company in case of accident, he is required to make a declaration that he does not suffer from any infirmity which will make him more than usually liable to accident, and the making of a false declaration would, in law, remove the liability of an insurance company to pay any amount to which the insured would otherwise become entitled. It has appeared to the writer to be one of the points of grave injustice in the Workmen's Compensation Act that no such declaration or medical examination is therein required for the protection of employers, who under the Act, in effect, give each workman a policy of insurance against accidents at the moment the Act comes into operation, or when he enters their service after that date.

Another matter which will require very careful attention is the settlement of the precise amount to be paid in case of accident. As the scale of compensation will be decided by the average weekly earnings of the workman, in case of fatal accident over a period of 3 years, and in case of personal injury of 12 months, or in either case where the full period has not been worked, for such less period as the injured person has worked for the employer from whom he claims compensation, it will be necessary to keep accurate records.

As we all are aware, at many collieries, sufficient care is not always taken to record the exact amount earned by those workmen who are paid at piecework rates, and if this system be continued there will be considerable friction and difficulty in fixing the exact amount of compensation.

As the provisions of the Act will affect a much larger number of men than the older Employers' Liability Act, and as the scale is definitely fixed, a careful record must be kept of the earnings of every person employed.

If a proper system of time-keeping is established, there should be no greater difficulty in keeping the proper records than there is in a factory or engineering works, although, perhaps, some little extra clerical work will be required, but this will be more than repaid by the greater certainty with which the amount of compensation to which the man is entitled may be ascertained.

In conclusion, the writer suggests that the following recommendations should be made to the colliery-owners through their associations,

and he believes that if they are generally adopted they will greatly facilitate, and lead to the most economical, working of the Act :—

(1) Whatever means are adopted by the owners for meeting the claims, whether by mutual arrangement with the workmen, by insurance with insurance companies, or whether the owners become their own insurers, all the payments shall be made from a central office, to which all claims shall be sent.

(2) One or more fully qualified mining engineers with experience in colliery-management shall be appointed in each district as inspectors, whose duties shall be to examine into the circumstances of all accidents in the interest of the colliery-owners, in the same manner that H.M. Inspectors of Mines enquire into accidents on behalf of the Government.

Such inspectors would become experts on the question of accidents, and would be able generally to assist colliery-managers by consultation and advice in the prevention of accidents.

(3) An independent consulting medical officer or officers should be appointed by the owners in each mining district, who would certify as to the nature of injuries in doubtful cases.

(4) The cost of the above officers shall be provided by the colliery owners or their insurers, at a rate to be fixed *pro rata* on the amount of wages paid.

(5) A small committee should be formed to examine the systems adopted, to ascertain the average amount of wages earned by each workman paid at piecework prices or employed by sub-contractors, and that the committee should draft a form of register to be kept at each colliery, showing the average weekly earnings of each person employed.

(6) The compensation for injury shall be paid on the certificate of the owners' inspector, or in doubtful cases on the joint certificate of the inspector and medical officer, in accordance with the scale provided by the Act, taking the average wages as shown in the colliery-register of earnings.

The above suggestions are made with the view of promoting discussion on the Act, and the writer hopes that they will draw from the members some expressions of opinion which will be helpful to all in their attempts to work the Act in the most satisfactory manner.

Mr. J. Richard Haines proposed a vote of thanks to Mr. Wain for his paper.

Mr. J. Heath seconded the resolution, which was agreed to.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, DECEMBER 11TH, 1897.

MR. GEO. MAY, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 27th and that day.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. ROBERT BARNARD, Colliery Manager, Gangootia Colliery, Deshergur P.O., Barakur, Bengal, India.

Mr. HUBERT PERCY BARRY, Superintendent of the Waihi Gold-mining Company, Limited, Waihi, New Zealand.

Mr. JAMES BARNET BAWDEN, Mining Engineer, Shaw Street, Coolgardie, Western Australia.

Mr. THOMAS PHILIP EDWARD BUTT, Mining and Mechanical Engineer, 1, Thornhill Villas, Mannamead, Plymouth.

Mr. G. SCHMITZ-DUMONT, Acting State Mining Engineer, Pretoria, Transvaal.

Mr. F. AUG. HEINZE, Mine Smelter and Railroad Owner and Operator, Trail, British Columbia.

Mr. FREDERICK JEFFERSON, Colliery Manager, Boldon Colliery, R.S.O.

Mr. BEDFORD MCNEILL, Mining Engineer, 25A, Old Broad Street, London, E.

Mr. ARTHUR HOPE MANNING, Engineer and Mine Manager, P.O. Box 88, Heidelberg, Transvaal.

Mr. THOMAS PEARSON MOODY, Civil and Mining Engineer, Hithurangi, *via* Auckland, New Zealand.

Mr. WILLIAM WATERS VAN NESS, Mining and Consulting Engineer, Bulawayo, Matabeleland, South Africa.

Mr. JOSEPH BURTON SETTLE, Mining Engineer, Darley View, Farnworth, near Bolton, Lancashire.

Mr. LAWRENCE W. TATUM, Mining Engineer and Metallurgist, San Luis de la Paz, Guanajuato, Mexico.

Mr. WILLIAM DENHAM VERSCHOYLE, Mine Manager, Alpha Gold-mining Company, Westland, New Zealand.

Mr. THEO. F. VAN WAGENEN, Consulting Mining Engineer, P.O. Box 589, Telluride, Colorado, U.S.A.

Mr. WILLIAM GLYDE WILKINS, Civil and Mining Engineer, Westinghouse Building, Pittsburg, Pennsylvania, U.S.A.

ASSOCIATE MEMBERS—

Mr. WALTER HAROLD BROCK, Umaria Government Colliery, Central Provinces, India.

Mr. CLIFFORD J. CORY, c/o Messrs. Cory Brothers & Co., Limited, Cardiff.

Mr. WILLIAM POLLARD HARRIS, Imperial Corporation of West Australia, Tourama District, Western Australia.

Mr. ARTHUR HASELDEN, Linares, Provincia de Jaen, Spain.

Mr. EUGENE KINNAIRD HASELDEN, La Carolina, Provincia de Jaen, Spain.

Mr. JOSEPH ANDREW JEFFREY, c/o Jeffrey Manufacturing Company, Columbus, Ohio, U.S.A.

Mr. JOHN ALDER LUMSDEN, Umaria Government Colliery, Central Provinces, India.

Mr. PERCY WILLIAM MAYOR, Linares, Provincia de Jaen, Spain.

Mr. FREDERICK HORACE MINARD, 409, Equitable Building, Denver, Colorado, U.S.A.

Mr. JOHN B. ROBSON, 12, Cardigan Terrace, Newcastle-upon-Tyne.

Mr. JOHN OLIVER SCOTT, The Glebe, Riding Mill-upon-Tyne.

Mr. H. G. STOKES, Silver Spur Silver-mine, Texas, *via* Stanthorpe, Queensland, Australia.

Mr. HAROLD FAIRBROTHER STRANGE, c/o Johannesburg Consolidated Investment Company, Limited, P.O. Box 590, Johannesburg, Transvaal.

Mr. W. H. WESLEY, The Anchor Tin Mine, Limited, Lottah, Tasmania.

Mr. W. WYBERGH, Consolidated Gold-fields of South Africa, Limited, P.O. Box 67, Johannesburg, Transvaal.

ASSOCIATE—

Mr. EDMUND COCKBURN, Back-overman, South Skelton Mines, Boosbeck, *via* Skelton-in-Cleveland, Yorkshire.

STUDENT—

Mr. ARTHUR G. B. WILBRAHAM, Mining Student, Anglo-American Club, Freiberg, Saxony, Germany.

DISCUSSION UPON MR. W. L. AUSTIN'S PAPER ON "PYRITIC SMELTING."*

Mr. W. L. AUSTIN wrote that Mr. Reynold's inquiry respecting the losses by volatilization in pyritic smelting touched on a very interesting point. In smelting ores by ordinary methods, there are always metallic losses not accounted for in the slags. These losses are usually ascribed to volatilization; but in reality they are of two classes: fine ore blown out of the furnace mechanically, and losses by volatilization proper. In pyritic smelting, without the use of carbonaceous fuel in the furnace, the volume of escaping gases is small, and consists mainly of nitrogen and sulphurous acid; but on account of the strong blast used, the current of

* *Trans. Fed. Inst.*, vol. xiv., page 111.

escaping gases has a considerable dust-carrying capacity. This dust can, however, be readily caught in suitable dust-chambers. As far as purely theoretical subjects can be investigated in the rush of commercial operations, the volatilization of the precious metals appears to be very slight, if any at all. The question then arises, if in pyritic smelting operations there is no appreciable volatilization of the precious metals in the absence of carbonaceous gases, to what extent are such metals assisted in volatilizing by the (for want of a better term) chemical carrying power of such gases? This matter is mainly of scientific interest, for the question of losses in the fumes has been definitely settled at more than one metallurgical works, by catching all the solid matter leaving the furnace, and allowing only the colourless gases to escape.

With regard to Dr. Carpenter's work, the smelting of siliceous gold ores with only a magnesian limestone flux, it can hardly be termed pyritic smelting at all, if under that title we are to understand the use of pyritic material as a source of heat in the blast-furnace.

Mr. Louis' comments on the dearth of specific, practical information on the subject of pyritic smelting, are perfectly justifiable. But it seems to be the settled policy of managers of successful technical establishments to keep their experience to themselves. This is a lamentable fact, as far as the scientific world is concerned; but it is, with few notable exceptions, a fact. It is hardly reasonable to designate such industries "pretty subjects of theoretical speculation that have not yet emerged from the purely experimental stage," because managers do not publish the experience which they have acquired in developing certain industries. It is, as Mr. Louis remarks, a curious fact that nothing has yet appeared in print regarding the details of the work now being carried out at a number of pyritic smelting-works, some of them quite large, and very successful commercially.

With regard to the employment of the internal-feed cylinder by the author, he advocated its use 10 years ago, and has never abandoned it; on the contrary, he is interested in further developing the system.

Dr. Bedson read the following account of "Experiments with the Shaw Gas-tester":—

EXPERIMENTS WITH THE SHAW GAS-TESTER.*

By Prof. P. PHILLIPS BEDSON, M.A., D.Sc., F.I.C., and J. COOPER, B.Sc.,
Durham College of Science, Newcastle-upon-Tyne.

At a meeting of the members of this Institute held on June 12th, 1897,† a demonstration of the working of the Shaw gas-tester was given by one of us, and in the discussion which followed Prof. Louis and Mr. M. Walton Brown drew attention to certain sources of inaccuracy in the machine and the method of working. The points raised by these gentlemen were such that doubts arose in the mind of the reader of this paper as to whether the excessive refinement claimed for the machine was altogether justified, and whether, in giving the demonstration, the apparatus had not been too leniently dealt with. It therefore appeared desirable that a further series of experiments should be made, and the outcome of these experiments it is proposed to lay before the members to-day.

Mr. M. Walton Brown directed attention to an arithmetical error in the calculation of the percentage of gas contained in a sample of air, the justification of which is at once recognized when one's attention is drawn to it. But when one calls to mind the accuracy which is claimed for this mechanical gas-tester it is not a little strange that those who have described the machine should not have directed attention to this pitfall and the necessity for an arithmetical correction of the experimental result.

In illustration of the nature of this source of error, an example may be cited. Suppose the ringing-line with a sample of coal-gas be found to be 9, *i.e.*, a mixture of 9 per cent. of coal-gas, and 91 per cent. of air is required to produce an explosion sufficiently powerful to propel the piston against the gong. If when for air there is substituted a mixture of air and gas, and now the coal-gas rings at 3·8 per cent., then, according to the instructions, the percentage of combustible gas in this mixture is to be found by subtracting 3·8 from 9, *i.e.*, 5·2 ; whereas, as a matter of fact,

* *Trans. Fed. Inst.*, vol. viii., page 161 ; and vol. xiv., page 350.

† *Ibid.*, vol. xiv., page 350.

this amount of combustible gas is contained in (100 — 3·8 =) 96·2 volumes of the mixture of air and gas. Hence the percentage is 5·2 × 100 ÷ 96·2 = 5·4—no inconsiderable error with a machine which is supposed to give the amount of combustible gas to 0·1 per cent. The error on this score alone may form a considerable percentage of the combustible gas, and vary within wide limits.

The second point raised in the discussion was that to which Prof. Louis gave utterance, viz., the justification of instituting a comparison between a pit-gas and a standard gas unless the standard gas was of the same composition as the pit-gas. The reply made by one of the authors at the meeting in June was not altogether correct, and experiments have shown the justice of Prof. Louis' contention, and further brought out the looseness with which the question of how the machine may be employed in the estimation of fire-damp in mine air has been treated by the various authors who have described the method of working.

Our experiments have been mainly directed to this point: several combustible gases have been tried against one another. The net result of these experiments has been to show that the same mixture will yield different amounts of combustible gas when tested in the Shaw gas-tester, according to the value of the "ringing-line" of the gas against which it is tested. So that the machine gives a relative, not an absolute result, and affords no information as to the nature of the combustible gas.

One or two examples will suffice to make this clear:—

(1) A sample of air from a mine was found by analysis in the Hempel apparatus to contain 20·45 per cent. of marsh gas, and with the appliance in the Shaw gas-tester a 20 per cent. mixture of this was made with air. In the Shaw gas-tester, a sample of coal-gas was found to ring at 9, when mixed with ordinary air, and against the 20 per cent. mixture coal-gas rings at 3·8. This, when corrected, corresponds to 5·4 per cent. of combustible gas.

(2) A sample of hydrogen was found to give a "ringing-line" of 11·3, when mixed with air; with the 20 per cent. mixture it was found to ring at 5·4, and this, when corrected, corresponds to a percentage of 6·2 of combustible gas in the mixture. The difference between 6·2 and 5·4 may not appear very large, yet neither of these represent the amount of marsh gas in the mixture, which, taking the analytical results, should be 4·09 per cent.

This statement shows at once that the results must be purely relative unless the standard gas is of the same composition as the combustible

gas in the mixture under examination. It will also be evident that by a simple calculation it will be possible to translate the amounts found by this machine into amounts of the combustible gas in the mixture, provided the relation between the "ringing-line" of this combustible gas and that of the standard gas be known; and in this manner fairly accurate results are to be obtained.

Thus, taking these results, the 6·2 per cent. against hydrogen may be translated into its coal-gas equivalent as follows :—$9 \times 6{\cdot}2 \div 11{\cdot}3 = 4{\cdot}9$ (by experiment 5·4). The result here must be considered only approximate, when one bears in mind the extreme delicacy of the apparatus and method.

In the several descriptions given of the Shaw gas-tester, it is generally stated that the "ringing-line" for pure marsh gas is 6 per cent. Now, taking this value, the above results may, by a similar calculation, be translated into amounts of marsh gas thus :—$6 \times 5{\cdot}4 \div 9 = 3{\cdot}6$ per cent., and $6 \times 6{\cdot}2 \div 11{\cdot}3 = 3{\cdot}29$ per cent. The percentage, based on analysis being 4·09.

(3) To give one other example :—A sample of marsh gas was prepared from sodium acetate and soda-lime, and this gas proved on analysis to contain 90·08 per cent. of marsh gas. The "ringing-line" for this gas was found to be 7, a 3 per cent. mixture was made of this gas and air, which, when tested against the marsh gas, gave a "ringing-line" of 4·2, the difference (7·0 — 4·2 =) 2·8, when corrected arithmetically gives a percentage of 2·92, which translated into marsh gas, on the above assumption, gives 2·65. The same mixture tested against coal-gas gave a "ringing-line" of 4·8, the coal-gas having a "ringing-line" of 8·3, the difference 3·5 when corrected yelding 3·67 per cent. If this be now converted into marsh gas by multiplying by $6 \div 8{\cdot}3$, the percentage of marsh gas is 2·44. The percentage, based on analysis, was 2·7. The difference here is not so great, but it must not be forgotten that this agreement has been arrived at by corrections of two kinds, an arithmetical one of the amount indicated by the machine, and the other by the system of translation from coal-gas or other ignitible gas, in terms of a marsh-gas with a ringing-line of 6.

Taking some twelve distinct estimations of marsh-gas in mixtures containing amounts varying from 0·38 to 4·2 per cent. of this gas, the results obtained by the Shaw gas-tester gave percentages which, when corrected, differ from the percentages based on analysis by amounts varying from 0·01 to 0·5. Whilst these results may at first sight appear very satisfactory, it must be remembered that the arithmetical correction

varies from 3 to 12 per cent. of the amounts of combustible gas indicated by the machine.

The influence of this arithmetical correction becomes more important the higher the "ringing-line" of the standard gas. Thus a sample of carbon monoxide, which analysis proved to contain 88·3 per cent. of carbon monoxide, was found to ring at 20. A 1 per cent. mixture of this gas was made, tested against carbon monoxide, and the ringing-line was found to be 19, a difference of 1. But this 1 part is contained in 81 of the mixture, hence the true percentage is $1 \times 100 \div 81 = 1{\cdot}22$.

The 1 per cent. mixture tested against coal-gas with a ringing line of 8·7 gave a "ringing-line" of 8·3, a difference of 0·4, the corrected value being 0·43 per cent. This result, when translated into a gas of a "ringing-line" of 20, becomes ($20 \times 0{\cdot}43 \div 8{\cdot}3 =$) 1·04.

To show the influence of using a standard gas of low ringing-line, we we will cite some experiments made with acetylene. The acetylene was made from calcium carbide, and contained 81·2 per cent. of gas absorbed by bromine. This gas was found to ring at 3·4. A 2 per cent. mixture of this gas was made, which when tried against the acetylene, gave a ringing-line of 1·6; the difference (3·4 — 1·6) represents 1·8 per cent., here the arithmetical correction is negligible. Tried against coal-gas, the mixture gave a ringing line of 3·9, coal-gas itself ringing at 8·3: the difference therefore is 4·4, which is the amount contained in 96·1 of the mixture, or a percentage of 4·5, the actual amount of acetylene being 1·62. But this 4·5 may be corrected and expressed in terms of acetylene with a ringing-line of 3·4: it then becomes ($3{\cdot}4 \times 4{\cdot}5 \div 83 =$) 1·8 per cent.

It would, therefore, appear that, if the Shaw gas-tester is to have a more extended use, it will be necessary that it should be calibrated for the commoner combustible gases; if coal-gas be employed as a standard, the estimations made by its use, may be translated into equivalents of marsh gas, and the detection of small amounts of this gas in mine air thus made feasible. But although such an air examination is readily made, still there are rapid methods for the chemical analysis of gases, which will yield results superior to those obtained by this mechanical tester, inasmuch as they also give information as to the nature of the gases themselves.

Since the above paper was read to the members, the table printed in Appendix A has been sent to one of the writers; it shows that the necessity for correcting the indications of the mechanical gas-tester, as proved by the authors, has been appreciated by the inventor.

APPENDIX A.—Table Showing the Exact Percentage of Fire-damp in Samples Tested by the Shaw Gas-tester with Standards Ranging from 6 to 12 per Cent., and Based on the Established Fact that 6 per Cent. is the Ringing-line for Pure Fire-damp (CH_4).

Small Cylinder Retreated from Standard Line.	Standards.												
	6 %.	6·5 %.	7 %.	7·5 %.	8 %.	8·5 %.	9 %.	9·5 %.	10 %.	10·5 %.	11 %.	11·5 %.	12 %.
0·5	0·52	0·49	0·45	0·42	0·40	0·38	0·36	0·34	0·33	0·31	0·30	0·29	0·28
1·0	1·05	0·95	0·90	0·84	0·82	0·76	0·72	0·68	0·65	0·63	0·60	0·58	0·56
1·5	1·57	1·45	1·35	1·27	1·20	1·14	1·08	1·03	0·97	0 93	0·90	0·86	0·83
2·0	2·08	1·93	1·80	1·68	1·59	1·51	1·44	1·36	1·30	1·24	1·19	1·14	1·11
2·5	2·59	2·40	2·23	2·09	1·98	1·87	1·78	1·70	1·62	1·54	1·49	1·43	1·38
3·0	3·09	2·86	2·67	2·50	2·36	2·23	2·12	2·02	1·93	1·85	1·77	1·70	1·65
3·5	3·59	3·32	3·10	2·91	2·74	2·58	2·46	2·36	2·24	2·14	2·06	1·98	1·91
4·0	4·08	3·75	3·53	3·31	3·12	2·83	2·80	2·67	2·55	2 44	2·34	2·25	2·17
4·5	4·56	4·23	3·95	3·70	3·49	3·30	3·14	2·99	2·85	2·73	2·62	2·52	2·43
5·0	5·05	4·68	4·37	4·09	3·86	3·64	3·46	3·30	3·15	3·02	2·89	2·79	2·68
5·5	5·52	5·10	4·78	4·49	4·23	4·00	3·79	3 61	3·45	3·30	3·17	3·05	2·94
6·0	6·00	5·55	5·19	4·86	4·59	4·34	4·12	3·92	3·75	3·58	3 44	3·30	3·19
6·5	?	6·00	5·59	5·24	4·94	4·68	4·44	4·22	4·03	3·81	3·71	3·57	3·44
7·0	?	?	6·00	5·62	5·30	5·01	4·76	4·53	4·32	4·14	3·97	3·82	3·68
7·5	?	?	?	6·00	5·64	5·34	5·10	4·83	4·61	4·41	4·23	4·07	3·92
8·0	?	?	?	?	6·00	5·66	5·38	5·13	4·89	4·68	4·49	4·32	4·16
8·5	?	?	?	?	?	6·00	5·69	5 42	5·17	4·95	4·75	4·57	4·40
9·0	?	?	?	?	?	?	6·00	5·70	5·45	5·22	5·00	4·81	4·63
9·5	?	?	?	?	?	?	?	6·00	5·72	5·48	5·25	5·05	4 87
10·0	?	?	?	?	?	?	?	?	6·00	5·73	5·50	5·30	5·10
10·5	?	?	?	?	?	?	?	?	?	6·00	5·75	5·53	5·33
11·0	?	?	?	?	?	?	?	?	?	?	6·00	5 76	5·55
11·5	?	?	?	?	?	?	?	?	?	?	?	6·00	5·77
12·0	?	?	?	?	?	?	?	?	?	?	?	?	6·00

Mr. A. L. Steavenson said that the members were very much indebted to Messrs. Bedson and Cooper for their extremely interesting and useful paper, which would add greatly to the value of the *Transactions*. He would like to ask, not only with respect to this, but to every machine, where should they use them? In the face, if they got a blower, there was no doubt about the fact of gas being there, and in a gallery they found it readily with a safety-lamp and knew what it was. It seemed to him that the only place where a testing-machine might be usefully employed was in the return-airways. Some 25 years ago, he used the Ansell indicator, but he had to give it up, because it was so uncertain in its action. He found that he could test with sufficient accuracy with the Liveing indicator. Again, supposing they wanted to try the edge of the goaf and took a sample of air, by the time the test was made the barometer had, perhaps, fallen or risen, and the conditions of the ventilation were entirely changed. With respect to the machine itself, he would

ask the inventor not to be discouraged by criticisms, but to continue to try and improve the apparatus, and he might be able to make a machine which was more reliable. He had pleasure in proposing a vote of thanks to Dr. Bedson and Mr. Cooper for their paper.

Mr. J. B. SIMPSON, in seconding the motion, said that the members were indebted to those gentlemen for their kindness in making the experiments with the Shaw gas-tester.

The vote of thanks was cordially adopted.

Mr. T. E. FORSTER asked whether differences in the composition of ordinary coal-gas were sufficient to make any difference in the results obtained by the machine. The gas made at colliery gasworks was not always of the best, and was not always purified as it might be.

Prof. H. LOUIS said that the paper had proved his apprehensions as to the working of the machine to be well founded. The members were much indebted to Dr. Bedson for his investigations, which showed that the machine could certainly be used for any gas, provided the gas was analysed first by the usual chemical method, otherwise the machine was useless to determine its composition, because, as he need hardly remind members, pit-gas was never pure marsh gas. Another source of error to which Dr. Bedson did not allude was that, since the machine was supposed to be used by bringing a sample of gas out of the mine in an elastic bag, the amount of gas in that bag had the greatest possible effect on the results obtained. It was quite certain that if the bag was under a certain pressure at one time and under another pressure at another time, the stroke of the piston of the machine would take in more gas on the one occasion than on the other. When, therefore, there were three distinct sources of error—variation of pressure, variation of chemical composition, and error of mathematical calculation—he thought that the machine could not be considered suitable for its purpose; its only advantage was that, with a little practice, one could get any results one pleased with it.

Dr. BEDSON exhibited the working of the Shaw gas-tester, and admitted the objection raised by Prof. Louis in regard to the pressure on the rubber bag. There was also the question to be taken into account of the amount of hydrocarbons absorbed by the rubber itself, the different distensions of the bag and the different pressures on the bag, and the different mixtures of gas with which they were testing. It might be his prejudice, but naturally he preferred the chemical

method, so long as they had to bring gas to bank. He thought that chemical analysis was to be preferred to this mechanical method of testing. As regards testing in the pit, they had lamps, and also the excellent Liveing indicator, which Mr. Steavenson had mentioned.

Prof. LOUIS read the following "Notes on the Iron Industry of the Urals."

NOTES ON THE IRON INDUSTRY OF THE URALS.

By Prof. HENRY LOUIS, M.A., A.R.S.M., Etc.

The following notes do not in any way pretend to present a complete account of iron-making in the Ural mountains; they consist merely of such information as the writer was able to collect during a rapid journey through the iron-producing districts of those mountains on the occasion of the recent International Geological Congress, at which he had the honour of representing this Institute. Although they thus necessarily form a mere sketch, yet he ventures to hope that they may prove of some use, firstly, because he is credibly informed that the mines and works which were visited are typical of the general run of practice in the Urals; and secondly, because the districts studied are those most immediately adjacent to the great railway line that is ultimately to connect St. Petersburg with Vladivostok, and are, therefore, the most favourably situated from the point of view of transport, which has always been, and of course still is, the great difficulty that confronts all mining and manufacturing enterprises in the Urals.

Fuel.—The Ural mountains are well wooded, the principal timber trees being pine and beech. The forestry laws of Russia are now fairly strict, and though the owners of mines and works may cut the timber which they need upon the lands granted to them, they must replant the space so cleared, in order to maintain the existing area of forest land. Forest land is never granted gratuitously; when works are to be established, a definite area of forest land, presumed to be sufficient for the needs of the works, is applied for, and, when granted, it is surveyed and the area to be cleared annually is determined and marked out, the value of the timber thus cut being paid to the State according to an official scale of prices, which scale will not be varied during the period for which the concession is given; this period can never exceed forty-eight years. A good many of the iron-works in the Urals are owned and worked by the State, and in their case the amount of wood to be cut annually is similarly fixed by the forestry officers.

All, or practically all, the blast-furnaces in the Urals work with charcoal as fuel. The charcoal is generally of fair quality, owing to the good character of the timber employed in its production, but it is at times far from being as thoroughly carbonized as it ought to be. It is burnt either in piles, which are generally rectangular and of medium size, or in kilns; these latter are mostly of what is called the Schwartz pattern, and consist of brick chambers rectangular in plan with a semi-circular arch, closely resembling a large rectangular coke-oven. Their capacity is about 1,700 cubic feet of wood, and the yield of charcoal is on the average 78 per cent. by volume. A kiln takes about 6½ days to burn, and 5½ days to cool, and treats about 24 charges in the year. There seems to be little if any difference in the quality of the charcoal produced by either method, though the yield is rather higher in the kilns.

Wood is largely used as fuel in direct-fired reverberatory furnaces. In some of the more modern works it is also used to generate gas in producers of various types, this wood-gas giving most satisfactory results.

Although the Carboniferous formation is known on both sides of the Urals, workable coal-seams have hitherto only been found on the western side, and even these extend over a relatively small area. They are worked to a certain extent, but the coal produced is of decidedly inferior quality, high in ash and sulphur, and making very poor coke when it cokes at all. Coke is, therefore, barely used in smelting operations. Coal is used to some extent in works in the north-western portion of the Urals, both in reverberatory furnaces and in gas-producers. A considerable proportion of the coal so consumed is produced by the small irregular coal-field traversed by the branch railway-line from Chusovaia to Luniefsk. The total production of coal in all the Urals was only 275,000 tons in 1894, and but little of this was used in the iron industry.

In recent times, naphtha-refuse has been used to some extent both for firing boilers and heating furnaces. Careful tests are said to have shown that the heating power of naphtha refuse is from 1·6 to 2 times that of good coal; 1 cwt. of refuse is said to be equal to 44 cubic feet of wood in heating puddling-furnaces by direct firing. It is used chiefly in the south-western portion of the iron-making district, where it can be most readily imported; in that area, the cost of Astrakhan naphtha-residue is about 23d. per cwt.

Peat exists in considerable quantity in various parts of the Urals, but, though it is used locally for firing boilers, and other purposes, the writer is not aware that it is used in any way in iron-production in the Urals.

Ores.—These are very abundant, and some, at any rate, are of good quality. The most important are, perhaps, the deposits of magnetite, that are worked in various places, chiefly at Mounts Visokaia and Blagodat.

Mount Visokaia consists of a low hill of considerable extent, united to the main railway line by a short branch line starting from Nishni-Tagil station. In this hill are immense deposits of magnetic iron ore, which supply mineral to no less than six important works; the chief workings belong to the Demidoff family and to the State. The geology of this district is far from being understood, and the nature and origin of the mineral deposits are equally obscure. The ore generally occurs in immediate contact with, and surrounded by eruptive rocks, mainly felsites and felsitic porphyry, together with an epidote rock which appears to form dyke-like masses traversing the ore. All the stratified rocks of the district are highly altered and consist of crystalline limestones, tufas, schists, etc.; rocks carrying beautiful specimens of grossularia are in places associated with the deposits. The whole district shows numerous slips, faults and shear-zones. The ore consists of massive magnetite with martite in places, while some portions of it carry small quantities of copper, and are separated by hand-picking. The ore seems to occur either in irregular beds or veins, or in flattened lenticular masses with a general easterly dip, this being also the direction of dip of the accompanying stratified rocks.

Russian geologists have explained the origin of these deposits as having been due to magmatic segregation from the eruptive rock-masses, which may possibly be correct. It is, however, by no means certain that the eruptive rocks are everywhere older than the ores, and it may yet be found that the ores were originally deposited in some other form (? as spathic ore by metasomatic replacement of limestone) and were subsequently converted into magnetite and martite by the action of the eruptive rocks. Again, even if the ores owe their origin to the eruptive rocks, there is no proof that they were necessarily produced by segregation.

The method of mining is extremely primitive; the ores have everywhere been followed down from the surface in big open-cuts, forming huge basin-shaped excavations; these are cut back in inclined terraces, ore and country rock being both removed, to enable the ore to be carted along these terraces and then in zig-zags up the sides of the excavation, and then again down the hillside to the loading stations on the railway line. Great economy in mining and handling would most probably result

from the use of low-level tunnels to which the ore might be dropped by gravity, to be run out in mine trams, but this self-evident method of working does not seem to have recommended itself to anyone, although the present system necessitates the mining of at least three times as much barren rock as of ore in order to keep the terraces open for carting. It is evident that Mount Visokaia contains immense reserves of iron ore, although with the exception of a few short exploring drifts no attempt has been made to determine the continuance of the deposits.

The ore is said to be extremely pure, to average about 65 per cent. of metallic iron, and to require very little or no fluxes in the blast-furnace. It is always calcined before use. The annual production of ore is given as about 130,000 tons. The following are average analyses of the ore, raw and calcined:—

	Raw.	Calcined.
SiO_2	2·60	2·49
Al_2O_3	2·86	3·06
FeO	16·71	7·92
Fe_2O_3	74·09	83·87
Mn_3O_4	2·84	1·52
CaO	0·40	0·71
MgO	trace	1·03
Cu	0·025	0·056
S	—	—
P	—	0·02

Mount Blagodat is situated some two miles from the Kushva station in the district of Goroblagodat, and is owned by the State. It consists of a hill about 500 feet high, containing immense masses of magnetic iron ore, and bears a considerable resemblance to the last-named deposit in a good many respects.

The geological associations are somewhat similar, there being immense masses of eruptive rocks, chiefly felsite and felsitic porphyry, together with altered stratified rocks, such as crystalline limestones. Numerous minerals such as grossularia, red garnet, epidote, etc., are met with. The ore is less pure than it is at Visokaia, and seems only to yield some 55 per cent. of iron. This is apparently due to the intermixture with the magnetite of finely disseminated chlorite and garnet. The unaltered ore is bluish or greyish-black in depth, but is superficially altered to a reddish-brown shade, probably by the decomposition of some of the associated minerals. This weathered ore is considered the better of the two kinds. Like the ore from the last-named mine, and indeed from most sources, this magnetite is calcined before use in large rectangular piles, such as are used for the other ores, and which will be subsequently referred to in more detail. The

object of calcining these magnetites is, no doubt, to produce structural rather than chemical changes. When calcined in piles in the usual way, 100 cubic feet of wood will calcine 21 to 26 tons of magnetite.

The method of mining (Fig. 6) is not dissimilar to that at Mount Visokaia. On account, however, of the height and steepness of Mount Blagodat, the mines are better laid out, and are worked in the shape of a number of quarries, the floor-level of which is above that of the surrounding country, so that the ore is carted down, not up. The same arrangement of sloping terraces, forming zig-zag cart roads is, however, employed here also. An attempt at scientific mining may be seen in the form of a rock-drill. There are four drills of the Dubois and Francois type, mounted on a tunnelling carriage, working with compressed air at 30 lbs. pressure. The drills are, however, very old-fashioned and defective in construction, and are, moreover, like most of the machinery the writer saw in this part of Russia, disgracefully kept. The air-compressor is over ¼ mile away from the drills, and the air main is small, so that the efficiency of the plant must be uncommonly low. Here, as elsewhere, the miners' hand tools are rough, primitive in design, and inferior in quality. The usual practice is to drill a face, by means of the machine, with a number of holes, 6 to 8 feet in depth, batches of which are then charged with dynamite and fired by means of ordinary fuzes. The method of mining appears to be both irregular and expensive. A certain amount of prospecting has been done here, a borehole having been put down to a depth of 700 feet, at which point it is still in ore.

Mount Blagodat produces about 60,000 tons of ore annually, and employs about 600 men.

There are numerous smaller magnetite deposits in the Urals that produce a good deal of ore. There are also very many deposits of chrome iron ore of good quality, containing 35 to 40 per cent. of chromic oxide. In the Urals, as elsewhere, this ore occurs in close connexion with serpentinous rocks, which are largely developed in various parts of this mountain chain.

Red hæmatites occur in various places. A wellknown locality is that of Puchia, where red and brown pisolitic and oolitic iron ores, apparently stratified, are found in limestones of Devonian age. This ore may carry up to 50 per cent. of metal, and is said to contain 1 per cent. of phosphorus. Other deposits of red hæmatite are said to occur in rocks of Carboniferous age in this district, and to contain up to 64 per cent. of iron.

Specular ore is also mined in the Urals.

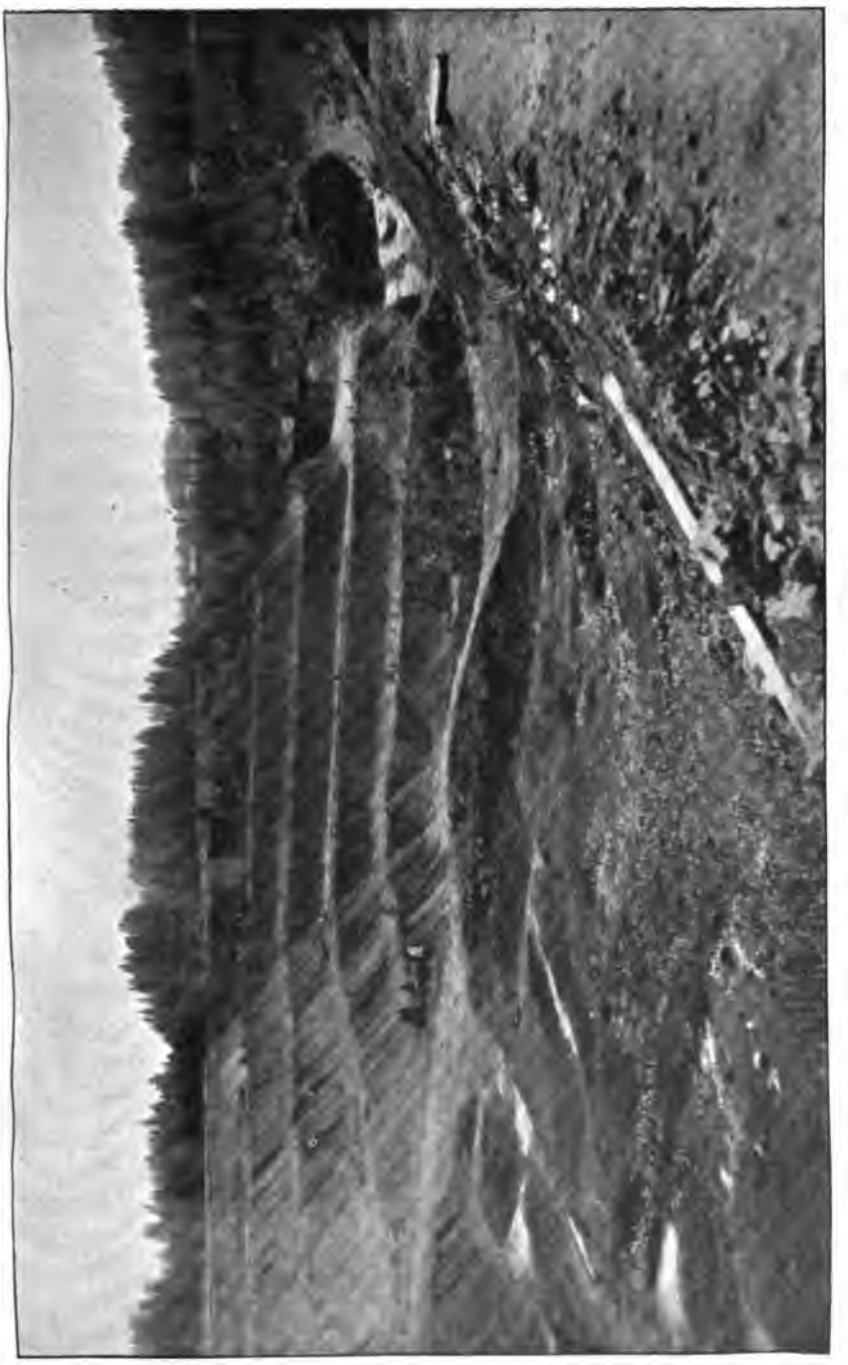


FIG. 6.—No. 9 IRON-ORE MINE ON MOUNT BLAGODAT.

Brown hæmatite and spathic iron ores are produced on a large scale in the important mining district of Simsk, at the mines of Bakal, and various others, which are divided amongst three owners, Messrs. Balachef, Prince Bieloselski-Bielozerski, and the State. These mines, which, together, produce about 100,000 tons annually, and employ about 1,750 men, are situated some 25 miles to the south of the railway line between the stations of Viasovaia and Suleia, the road being execrably bad in summer, though it is said to be well adapted to winter traffic by means of sleds.

All these mines present similar geological features; the country consists of schists of Lower Devonian age, interstratified with dolomites and overlain by quartzites, which constitute the serrated ridges of the hills; these rocks are underlain by other beds of quartzite, the ore-bearing formation being bounded by the upper and lower quartzite-beds. All these formations are traversed by dykes of diabase, at times interbedded amongst the stratified rocks. The ore, when opened up in depth (250 feet below its outcrop), is seen to be a massive siderite or spathic ore, but nearer the surface (down to a depth of over 150 feet) it has been converted into brown hæmatite. It is distinctly interstratified with the shales, and shows structure parallel to the stratification, whilst irregular masses of dolomite project into it, the passage between the two being apparently gradual. There can be little doubt that the calcareous rocks have been converted metasomatically into spathic ore by the action of ferriferous solutions, the origin of which may possibly be connected genetically with the outbursts of diabase. The spathic ore has been converted superficially into brown hæmatite by atmospheric action in the ordinary wellknown manner, the limit of this action being locally about 200 feet below the outcrop of the ore. These deposits thus present well marked genetic affinities with those of Bilbao.

The method of mining is practically identical with that described at Mount Visokaia, the principal mine (Fig. 7) being 120 feet deep, and being also cut into terraces in the same way as the latter. This mine produces about 500 tons of ore per day, but can only work in the summer months, say for 100 to 120 days in the year. The climate here is severe, as the mines are situated 5,000 feet above sea-level. The brown ore can be got with the pick only, but the spathic ore, of which a relatively small quantity is produced, requires blasting. The miners are paid according to the amount of ore got, the price being said to vary from 10s. 6d. to 17s. per ton, the lower figure being paid for brown ore, and the higher for spathic ore; the owners furnish tools and dynamite, the consumption of

FIG. 7.—NO. 2 IRON-ORE MINE AT BAKAL, BELONGING TO MESSRS. BALACHEF.

the latter being only about 13 cwts. per annum. The above price is paid for both getting the ore and for carting it out of the mines, which is done in small carts carrying about 6 cwts. If the above prices are correct (and they certainly seem far too high), it only serves to show how badly the mines are laid out and organized, and how dear cheap labour can become, seeing that the average wages of miners in the Urals are only about 1s. 6d. per day.

All the ore is calcined in big rectangular piles, containing about 10,000 tons of ore. When brown ore is being calcined, a bed of cord-wood about 4 feet 6 inches deep is laid down, and upon this the ore is piled to a depth of about 19 feet; for spathic ore, the proportion of ore to fuel is about 3 to 1. These piles will burn for about one month.

All the ore is transported to the railway during the winter time by means of sleds drawn by one horse. Each sled will carry 10 to 15 cwts. of ore, and makes five trips per week; some 400 horses are thus employed.

The most recent complete statistics published by the Russian Department of Mines, refer to the year 1894; in that year there were in the Urals 868 iron mines of all sorts in operation, and these produced 880,000 tons of ore, with the labour of nearly 21,000 men, or but little over 40 tons per head per annum. Compared with the total production of iron ore in Russia, the output of the Urals has commenced to decline in recent years, as shown by the following figures:—

Year.	Iron Ore Produced in	
	The Urals. Tons.	All Russia. Tons.
1886	673,000 ...	1,072 000
1890	907,000 ...	1,768,000
1894	880,000 ...	2,447,000
1896 (estimated, unofficial)	572,000 ...	1,600,000

Blast-furnaces.—There are a very large number of blast-furnace plants scattered throughout this region, each works having as a general rule two furnaces, though the numbers vary from one to four. The furnaces are mostly small, the average output being about 20 to 25 tons of pig in 24 hours. They are usually somewhat old-fashioned in type, though improvements have recently been introduced in a good many places; a certain number of Rashette furnaces (oval in plan) are still in operation, although they are gradually being replaced by the ordinary circular type. On account of the severity of the climate, furnaces and pig bed are enclosed in a substantial brick building, which usually has a cupola-

like roof covering the furnace-tops (Fig. 8). Both hot and cold blast are employed, the blast-pressure being, as a rule, between 1 and 2 lbs. to the square inch. All these works are situated in valleys, so that large water reservoirs can be obtained by constructing a low dam across the valleys in question: some of these reservoirs constitute veritable lakes several miles in circumference. The object seems to have been not only to obtain the water required in the works, but also a cheap and ready source of power, most of the works having been built before the utilization of the blast-furnace gases for steam-raising had been introduced. The sites thus selected for the works are convenient for obtaining their supplies of fuel, but often present serious disadvantages as regards both carrying in the ore, and disposing of their production of pig-iron and castings. A more detailed description of a few of these works will perhaps give a sufficient idea of the stage of devolopment of the pig-iron industry.

Simsk Works, owned by Messrs. Balachef Brothers, and smelting the calcined ores from the Bakal district, are situated about 5 miles from the station of that name. They are now being connected to it by means of a narrow-gauge tramway. There are two blast-furnaces, the section of which is shown in Fig. 1 (Plate XIX.). They have brick stacks, iron hooped, and carried on brick arches; as is the case with most of the furnaces in the Urals, the crucible and all the stack up to the boshes, are not built of brick, but are made by ramming a suitable mixture of sand and clay round a wooden pattern into an outer retaining wall. This part of the furnace lasts for about 20 months. The furnaces are open-topped, the gases being drawn off by a side pipe.

The charge consists of :—

Fuel, 4 boxes of charcoal (equal to 60 cubic feet).
Ore, about 0·6 ton (calcined spathic ore and brown hæmatite, containing 60 per cent. of iron).
Flux, dolomitic sand, equal to 10 per cent. of the ore.

Each furnace puts through 65 to 75 charges in 24 hours. The charcoal is dropped in direct. The ore and the dolomite used for flux are mixed, scattered uniformly round the circumference of the furnace, and then shovelled into it. The charcoal and ore-sheds are some little distance from the furnace-bottom; the charges are adjusted there, run in boxes suspended from a roller, running on an overhead rail by means of rope haulage, to a small rope-hoist, driven by a 24 horse-power turbine, which lifts them to the level of the furnace-top. They are run in the same way, but by hand, from the hoist to the furnace-mouth. There are about 20 men engaged per shift on the furnace-top, the same gang working both furnaces.

The blast is produced by means of three horizontal blowing cylinders, lying side by side, and driven by a 125 horse-power vertical turbine. Each cylinder is 5 feet in diameter, 5 feet stroke, and makes 17 to 22 strokes per minute, 19 being about the average for the two furnaces. The quantity of blast is about 5,000 cubic feet of air per minute, at a pressure of $3\frac{1}{4}$ to $3\frac{3}{4}$ inches of mercury. The blast is heated in cast-iron pipe-stoves, containing 11 rows of oval pipes, with 3 arches in each row; the temperature is between 300° and 400° Cent. There are 3 tuyeres, water-cooled, about 4 inches in diameter; the nozzles, about $2\frac{1}{2}$ inches in diameter, enter these tuyeres, but are not packed, so that much air escapes backwards and does not enter the furnace at all. The front is closed, with a short tymp; the cinder runs from the notch over an inclined cinder-bed, where it sets, and is pulled away by hand. The production of cinder is not large, and there are 2 to 3 flushes to each cast.

The pig-iron produced is chiefly grey and of fine quality, largely used for foundry purposes. Each furnace produces about 20 tons in summer and 30 tons in winter per 24 hours. There are 4 casts in 24 hours from each furnace, the iron being run into sand-moulds. There are about 10 men at work on the pig-bed per shift.

There is a foundry attached to the works, in which the pig is remelted in a wood-fired air-furnace. Very fine castings are produced; their value is stated to be £17 per ton at the works. There are also steel works, etc., attached to these works, which will be referred to later on. There are said to be over 600 men employed at these works, of whom 80 are engaged about the blast-furnaces.

The average year's work of these two furnaces is as follows :—

Ore smelted	16,600 tons.
Fluxes smelted	1,350 ,,
Charcoal	2,250,000 cubic feet (about 11,000 tons).
Pig-iron produced ...	10,000 tons (or 59·5 per cent. of the ore).

The Satkinsk Works are the property of the State; they are situated some 10 miles from Suleia station, and also treat the ores of the Bakal district. There are two blast-furnaces, an older one of the Rashette type 16 feet by 10 feet in the boshes, with four tuyeres in each of the longer sides, the cinder notch in one of the shorter ends, and the tap hole in the other. The second furnace is a newer one, and is circular, 13 feet in diameter at the boshes, with five tuyeres. Both are of the same height, namely 47 feet. The older furnace produces about 48 tons of pig-iron per day, whilst the newer one produces about 29, but the latter works far

more economically as regards fuel; it treats 1·4 tons of ore to the ton of charcoal, whilst the Rashette furnace only treats 1·25 tons with the same amount. The comparison thus afforded between these two types of furnace is the main point of interest about these works. According to the governmental returns, the average year's work at these furnaces is:—

Ore smelted	32,500 tons.
Slags	110 ,,
Fluxes	3,000 ,,
Charcoal	3,400,000 cubic feet.
Pig-iron made	19,500 tons (60 per cent.).

There are no less than 200 men employed about these furnaces, and it may be interesting to state that the area of forest land apportioned to the use of these works is 334,300 acres. As very little except blast-furnace work is done at these works, there being only five puddling-furnaces here, an idea can be formed of the amount of forest land required for the production of charcoal iron, though there are few works that have so large a proportion as the above.

It is estimated that an acre of forest land yields about 3,430 cubic feet of wood fit for charcoal burning, and that this wood produces about 2,300 cubic feet of charcoal; the wood cut for charcoal seems to be at least of 60 years growth, so that the minimum area of forest land that will support a blast-furnace can readily be calculated. The official estimate is, that an acre of Ural forest land will give at most 2,600 cubic feet of charcoal, and often only half that amount.

The Baranchinsk Works (Fig. 8) are government works, using principally ore from Mount Blagodat. There are two furnaces here, No. 1 being a modern circular furnace, the section of which is shown in Fig. 2 (Plate XIX.) whilst No. 2 is an old-fashioned Rashette furnace, with boshes about 12 feet by 18 feet, and with two tuyeres in each of the longer sides, and one in the back (not in use at the time of the writer's visit); the cinder notch and tap hole are both in front. No. 1 furnace is externally octagonal in plan, the upper part of the stack being contained in a retaining wall of red brick hooped and braced with iron, whilst the portion below the boshes is iron-cased. There are four tuyeres in the alternate panels of the octagon; these are small spray tuyeres. Both furnaces are of the same height, and both are worked with open tuyeres, *i.e.*, with the nozzles not clayed in. The furnaces are open topped, and no hot blast is used. The charge consists of six boxes of charcoal, each weighing about 6 cwts., which are dumped into

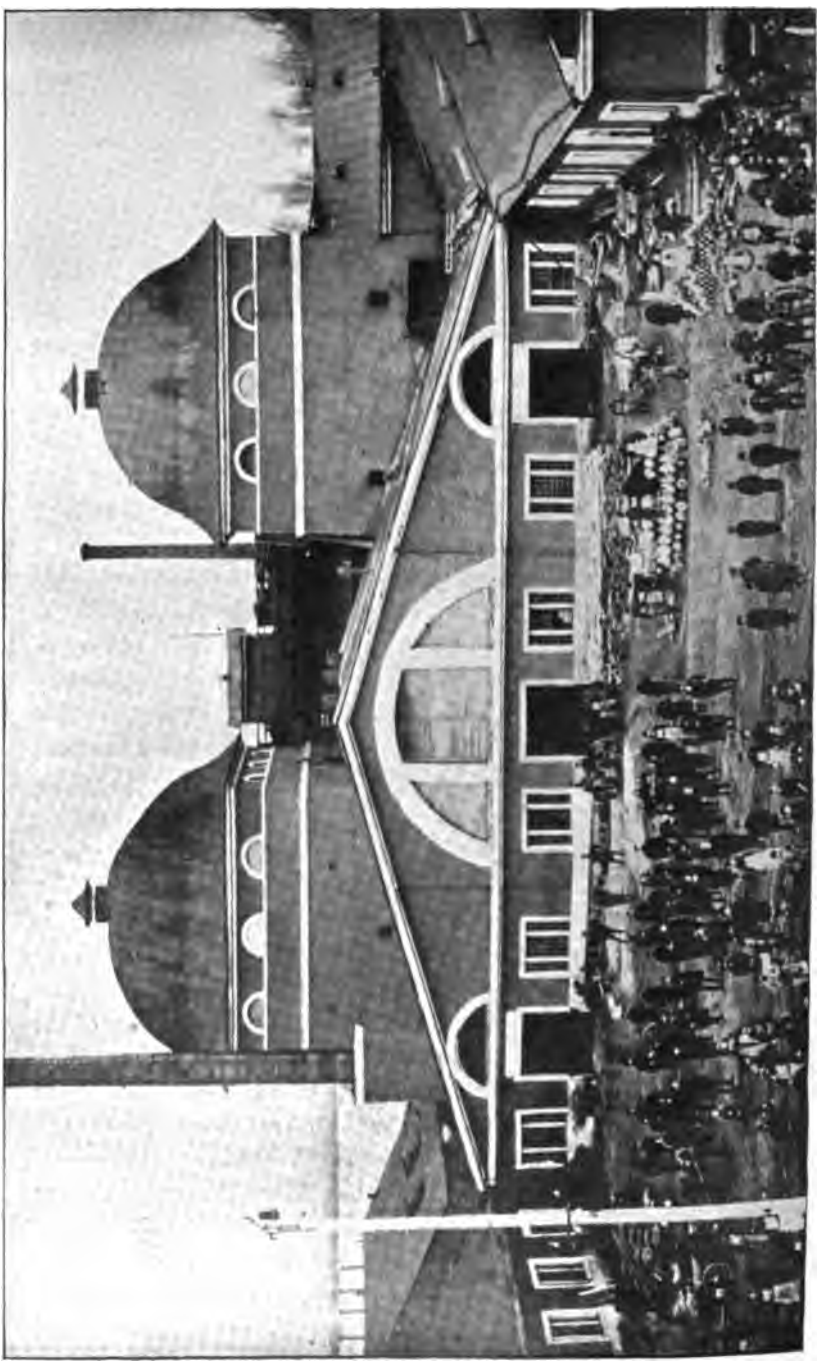


FIG. 8.—BLAST-FURNACES AT BARANCHINSK.

the furnace followed by a number (apparently irregular) of flat sheet-iron trays containing ore (calcined magnetite and some calcined brown hæmatite), foul slag with shots of iron, and limestone (about 5 per cent. of the weight of the ore). It is said that the Rashette furnace will take about 70 boxes of charcoal with its proportion of ore and flux, whilst the circular No. 1 furnace takes about 45 boxes. The new furnace is said, however, to do rather the better work of the two. The blast is generated by means of a pair of horizontal cylinders, 5 feet 8 inches in diameter and 5 feet 9 inches stroke, driven at 20 strokes per minute by a 90 horse-power turbine, and forcing 8,500 cubic feet of air per minute at a pressure of 2¾ inches of mercury. Another similar pair of cylinders, steam driven, is kept in reserve in case of need.

The water is usually distributed in all the Ural works by means of large wooden tubes built up of staves and iron-hooped. The water is said never to freeze, provided it is kept running.

In addition to the blast-furnaces, there are at the Baranchinsk works a large shell-foundry, and fairly well equipped machine shops for turning and finishing the shells. The iron is remelted in the foundry by means of two wood-fired air-furnaces.

The average annual results of these works are :—

Ore smelted	15,000 tons.
Flux	600 ,,
Charcoal	2,750,000 cubic feet.
Pig-iron produced	8,800 tons (58·9 per cent.).

There are about 100 men engaged about the blast-furnaces, together with between 500 and 600 outside labourers.

At *Chusovaia* there is a big ironworks owned by a French limited liability company, called the Kama Company. There is here one blast-furnace which has only been built some 4 or 5 years, and is, therefore, a good example of the most modern type of blast-furnaces in the Urals. The furnace is about 60 feet high; the stack of brick, iron-hooped, rests on brick pillars, the crucible and lower part of the furnace being cased in boiler-iron. The tuyeres, of which there are three, are ordinary water-tuyeres, and the blast-nozzles are packed tightly into them, the pressure of the blast being from 1½ to 1¾ inches of mercury. There are a pair of iron pipe hot-blast stoves, heating the blast up to about 400° Cent. The furnace has a closed top; this consists of an iron lid with a central pipe for taking off the waste gases. This pipe is connected with the gas downtake by a hinged joint in such a way that the cover, which is counterpoised, may be turned up, and leave the top free when the furnace is to be charged.

The charcoal, most of which is burnt at the works, seems to be rather inferior in quality; it is swung over the open furnace-top, by means of a crane, in an iron box with a drop bottom, which opens on knocking off a catch. The ore and flux are charged in a more complicated manner. A travelling-carriage running on rails, which is of about the same diameter as the furnace-top, is placed just clear of the top. On this carriage rests a circular iron box rather over a foot deep, the bottom of which consists of an iron plate with radial slots, having an angular width of some 10 degrees; there is a second similar plate below this one, which can be turned through a little over 10 degrees, so that the slots in the lower plate can be made either to coincide with those in the upper one, and thus open the box, or else to coincide with the spaces between the slots in the upper plate, when the bottom of the box is closed. This is its usual position, and when thus set, a box of about one-third its diameter with a conical bottom, containing the weighed ore and fluxes, is hoisted into the middle of the above shallow box. By loosening a catch and hoisting, the ring-shaped walls of this second box are lifted clear of the bottom, when the mixed ore and flux slide off the cone into the annular space in the larger box. Thus prepared, the carriage is pushed into position over the furnace top, when, by turning the lower plate of the large box, the ore and flux are allowed to drop evenly distributed into the furnace. Seeing that the charcoal is in very big lumps, whilst the rest of the charge is broken very small, it may be questioned whether it is worth while making use of so elaborate and cumbersome a distributor. The ore is mainly Puchia ore, with about 15 per cent. of magnetite.

The make of pig-iron is said to be about 20 tons per day of white iron, which is cast in chills; these are arranged in rows running downwards from the furnace, and each row is filled in turn by means of a revolving spout. The pig iron produced is said to contain 1 per cent. of phosphorus.

The average annual work of this furnace is as follows:—

Ore smelted	7,300 tons.
Fluxes	1,100 ,,
Charcoal	1,235,000 cubic feet.
Pig-iron made	3,100 tons (42·4 per cent.).

The production of pig-iron is one of the less important operations at these works, which also make wrought iron and steel; the same company owns two other works, at one of which there are four blast-furnaces producing something like 20,000 tons of pig-iron annually.

Although the writer happened to have visited none of their works, this portion of the subject would be incomplete without some reference to the

work done in this district by the Demidoffs, who are the leading iron-masters here. Their principal establishments are at Nishni-Tagil and Nishni-Saldinsk. They own altogether 2,345,000 acres of land of which 1,980,000 are forests. They have 11 blast-furnaces in operation, 1 of which is reserved for making ferro-manganese and ferro-silicon, and occasionally ferro-chrome, whilst the other 10 make ordinary pig-iron. Their records go back to the year 1758, when they produced 6,650 tons of pig-iron and about half that quantity of wrought iron. In 1895, the production of their blast-furnaces was:—

	Tons.	
Pig-iron ...	61,900	(P, 0·06 per cent, S, 0·02 per cent, Cu, 0·06 per cent.)
Ferro-silicon ...	130	(20 per cent. Si)
Ferro-manganese	230	(80 per cent. Mn.)
Total	62,260	

The ore smelted in this year amounted to 95,400 tons, the bulk of it being magnetite from the Demidoff mines on Mount Visokaia, containing 65 per cent. of iron. The other ores are brown hæmatite from Schilofsk, with about 57 per cent. of iron when calcined, and manganiferous ore from Sapalsk with over 50 per cent. of manganese. These ores are now largely calcined in kilns instead of in piles, much fuel being thereby economized. The consumption of charcoal in the blast-furnaces to produce the above amount of pig-iron was 15,640,000 cubic feet; it is said that the charcoal smelts its own weight of pig-iron in the furnace. Various forms of hot-blast stoves are used, some being iron pipe-stoves, heating the blast to 250° Cent. and some Cowper stoves heating it to 500° Cent.

The works of the Demidoffs are thus, evidently, the most progressive in the Urals, and the iron industry of this region largely owes its present development, no less than its original expansion, to the enterprise of this princely family.

Reference must also be made to the works at Kussa and Kishtim, in both of which places, though especially in the latter, small iron castings are made which are remarkable no less for their artistic modelling than for their beautiful finish. The better qualities will fully sustain comparison with the famous Berlin castings, and have, indeed, but few equals in the world.

The Urals are gradually losing their relative importance as the leading district for the production of pig-iron, as shown by the following table:—

Year.	Urals. Tons.	All Russia. Tons.
1886	300,000 ...	520,000
1890	400,000 ...	912,000
1894	534,000 ...	1,312,000
1896	571,600 ...	1,600,000
1897 (first six months)	332,600 ...	914,000

Wrought Iron.—This is still largely made in the Urals, being used extensively in the form of bars by country smiths, and also being worked up into the wellknown Russian sheet iron; the manufacture of these sheets is to-day practically still identical with the process as described by Dr. John Percy in 1871, and will hence not be further described here. Some iron rails of light sections are rolled in places, some boiler plate is also made, as well as merchant bars of various sections. Iron is still made to some extent in charcoal fineries, but these are now dying out and being replaced by puddling-furnaces, which were first introduced about 1850. The former are still preferred for making sheets. The latter are of various types, single and double, and mostly wood-fired, though in the south-western portion of the district naphtha residues are being used with advantage, and seem to be coming into favour.

Miniarsk Works.—These works are situated about 2 miles from the station of the same name, with which they are connected by a narrow-gauge tram line. They make only puddled iron and finished iron, chiefly round, square and flat merchant bars, tees and angles, plates, sheets, etc. The pig-iron is obtained from the Simsk blast-furnaces, both works belonging to the same owners; the pig-iron is chiefly grey, with a little mottled and white. The original form of puddling-furnace was a double furnace, wood-fired, the draught being produced by a stack; these produced only 29 cwts. of puddle bar in 24 hours, and are hence being replaced by oil-fired furnaces; the last one was just being torn down at the time of the writer's visit.

The oil-fired furnaces are also double furnaces, worked by a puddler at either side; there is one helper to each furnace per shift. There is of course no fire-place, but merely the puddling chamber, and beyond it a heating chamber, in which the pig-iron is heated to redness before being charged into the puddling-furnace proper. Above this heating chamber rises a short stack containing a serpentine cast-iron pipe, making three bends, one vertically above the other. The blast is made to pass through this pipe, and is thus heated to a certain extent; it is then carried by a pipe to the opposite end (corresponding to the fireplace-end in ordinary

furnaces) of the furnace, where it enters through a narrow horizontal slot; just above this slot there are a couple of narrow nozzles connected to a pipe about 2 inches in diameter, through which naphtha residue is forced by means of a small pump. The construction of this burner is shown in Figs. 3 and 4 (Plate XIX); it is made of about $\frac{3}{8}$ inch iron plate. As the oil drops down in front of the thin flat air-blast, it is caught by it and blown into spray, which at once ignites, forming a blow-pipe flame, which is directed down upon the bed rather beyond its centre. By regulating the supply of air and oil, the flame may be made reducing or oxidizing at will, and is under complete control. The roof of the puddling-furnace forms a much flatter arch than is usual in coal-fired reverberatory-furnaces. The blast is produced by a Root blower. This furnace has air-cooled boshes and is fettled with talcose schist. The firebricks used in these furnaces, as well as in the mill-furnaces, are silica bricks, made by crushing burnt quartz, mixing with 2 per cent. of lime, moulding and burning; their cost is said to be about £3 15s. per thousand. This furnace takes a charge of 11¼ cwts. of pig iron, and makes 35½ cwts. of puddle bar in 24 hours. The forehand puddler is paid 3s. 2½d. per day, the second hand, who takes the back door of the furnace, 2s. 6¼d., and the helper 1s. 7d. per shift. In these furnaces 1 cwt. of naphtha residue will produce 4 to 5 cwts. of puddled iron, the latter figure being high. The iron produced is of very high quality, of very even grain, and crystalline rather than fibrous. The balls are shingled under a helve. The mill furnace is of the usual type, fired with wood-gas. The producer consists of a rectangular brick chamber with firebars at the bottom, about 5 feet square and 17 feet deep down to the bars, burning 340 cubic feet of wood in 24 hours. The wood is introduced by means of a cast-iron box, about 4 feet by 2 feet 6 inches by 2 feet deep; the cover is set in a water-seal and the bottom is hinged, so that the producer can be charged without any air being admitted. The rolls are of the usual type, three-high, driven by turbines on vertical spindles.

A very large and handsome new puddling and rolling-mill is just being finished. There are 8 double puddling-furnaces, oil-fired, the burners being identical with those already described. The blast is, however, heated by passing below the bed of the furnace, which is fitted with water-boshes. These furnaces are built in pairs, a Galloway boiler being placed between each pair and fired by their waste heat; the boiler-water is heated by passing through the water-boshes of the furnaces. There are 2 Worthington pumps respectively for circulating the water and for pumping the oil from a storage-tank to the furnaces. There is a 2½ ton steam hammer,

and two mill trains driven by an engine of 375 indicated horse-power. The reheating furnace is fired with wood gas, and is regenerative.

These works employ about 1,000 hands all told. It is worth noting that they are laid idle two to three months every year, between July and September, to allow time for getting in the harvest. In 1894, there were 10 puddling-furnaces at work, producing 6,700 tons of puddle-bar.

Chusovaia Works.—There are here 16 puddling-furnaces, all wood-fired; they are double furnaces, the men working side by side at the doors marked 1 and 2 in the sketch-plan (Fig. 5, Plate XIX.). *A* is the fire-place, *B* the furnace body, and *C* a preheating stove for heating the pig-iron before it is charged into the furnace proper. The waste heat is used for firing boilers. Each furnace uses 340 cubic feet of wood in 24 hours, and produces up to 38 cwt. of blooms in that time. The blooms are shingled under a small steam hammer, and reheated in a large Bicheroux furnace fired with coal. The mill train consists of 1 pair of breaking-down rolls and 1 pair of mill-bar rolls, both two-high. Some of the iron is at times finished in the steel rolling-mill, consisting of a three-high train; in this mill re-heating is done in Siemens furnaces. These works turn out about 12,700 tons of puddle-bar per annum.

The statistics for 1894 show that there were in the Urals in that year 309 charcoal-fineries and 365 puddling-furnaces, which produced respectively 78,000 tons of blooms, and 290,000 tons of puddle-bar. The progress of wrought iron manufacture is shown by the following table:—

Year.	Urals. Tons.		All Russia. Tons.
1886	190,000	...	357,000
1890	225,000	...	426,000
1894	289,000	...	570,000
1896 (estimated, unofficial)	244,000	...	494,000

Steel.—Up to comparatively recent times considerable quantities of puddled steel, cement steel and crucible steel were produced in the Urals. The open-hearth process and the Bessemer process were both introduced in the same year, 1876, by the Demidoffs, whose services to the iron industry of this region have already been referred to, and these newer methods of steel-making have, to a great extent, replaced the older ones. There are at present in the Urals, two Bessemer plants with two converters each, at Nishni-Saldinsk and at Katav-Ivanofsk. Open-hearth furnaces are more numerous, these being in operation at 12 works, with a total of

22 furnaces. The quantities of the various kinds of steel made in the Urals in 1894 were as follows :—

	Tons.
Cement steel	1,200
Puddled ,, ...	1,900
Bessemer ,, ...	48,200
Open-hearth steel...	30,000
Crucible ,, ...	4,100

The Bessemer works present no especial peculiarities; the converters are 4 tons converters, and make 30 blows in 24 hours, though the actual time of a blow is only 12 to 14 minutes. The steel is cast into ingots weighing 5 to 6½ cwts., and practically the whole of it is used in rail manufacture; the demand for rails in Russia is a rapidly growing one, and this district in particular is well situated for supplying the Trans-Siberian railway now under construction.

At the Simsk works, there is one open-hearth furnace making Siemens-Martin steel. There are three gas generators identical with those at Miniarsk situated close to the furnace, wood being the fuel used. The gas and air-valves are reversed every half-hour. The brick used is a silica-brick identical with that used at Miniarsk. The furnace-bottom is composed of lumps of chrome-iron ore, resting upon a brick foundation, the actual bottom consisting of crushed chrome-iron ore mixed with 2 per cent. of lime, rammed into the furnace and fired. It makes an admirable bottom, very hard and close in texture, and extremely infusible. The furnace takes a 10 tons charge of pig and scrap and more or less ore, according to the proportion of scrap available; the ore used is the ordinary calcined Bakal ore, such as is used in the blast-furnaces at these works. The actual time of working a charge is about 7 hours, but only two charges are got out in 24 hours. The steel produced is said to contain 0·12 per cent. of carbon and 0·03 per cent. of phosphorus. It is partly cast into ingots, which are sent to Miniarsk to be rolled, and is partly used for making steel castings, which are rather rough and imperfect.

At Chusovaia, the ingots are cast by ascension in groups of 8 ingots placed round a central vertical runner. There is nothing else about the steel-making, as practised in the Urals, that calls for any special remark.

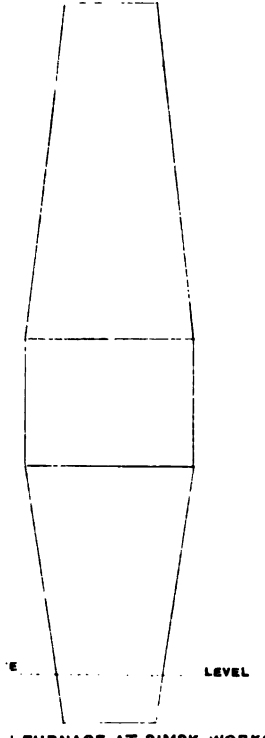
Whilst the production of steel, both in Russia as a whole and in the Urals, has been growing rapidly, the growth is confined to the cheaper grades, namely, Bessemer and open-hearth steel, the output of the other qualities showing a gradual decline. The Urals never occupied as pro-

minent a place in the Russian steel-manufacture as they do in that of pig and bar iron; they produce, and have for some time past produced, just about 10 per cent. of the total output of the empire.

It may be noticed that in this rapid sketch of the iron industry of the Urals, the writer has dwelt more especially upon the more primitive processes, and such as are likely to be dying out. But this is merely because these are the processes that future observers will have less opportunities of studying, and not because he attaches to them any special industrial importance, or that he wishes to gloss over the real advances that have been made in this district in recent years. There is no doubt much to be done before the district, as a whole, can come abreast of the times, though some of the best works are conducted on thoroughly sound principles. The most striking point about the industry is its wholesale waste of human labour. To produce 500,000 tons of pig-iron, there are 7,500 men employed about the blast-furnaces, whilst the total iron industry of the Urals employs no less than 48,800 workmen, with 85,800 labourers; to these we must add the 20,900 men employed in the mines, giving a grand total of 155,500 men engaged in the iron industry of this district, who only produce, say, 250,000 tons of pig and and an equal weight of malleable iron and steel. Making every allowance for the inclemency of the climate, as well as for the fact that wood-cutting and charcoal burning necessitate the employment of a very large number of men, who are, of course, included in the above figures, the quantity of labour is out of all proportion to the production of iron, and we have once again the fact demonstrated that low wages do not necessarily mean cheap labour.

As to what the future of this iron-producing region will be, it is difficult to draw any very certain conclusion. Hitherto experience in every part of the world has shown that charcoal iron cannot in the long run compete against iron made with mineral fuel, and that the proper site for ironworks is on the fuel-producing coal-fields, and not at the mines yielding the ore. In the case of the Urals, there are, however, a few considerations to be taken into account that cannot be paralleled elsewhere. In the first place, a good many of the works belong to the State, which will keep them up for the sake of the high quality of their products, the latter being required for military purposes, in which cost is a subordinate consideration. Then, again, the principle of conservation of the forests, now being applied in the Urals, has not, so far as the writer knows, been tried in

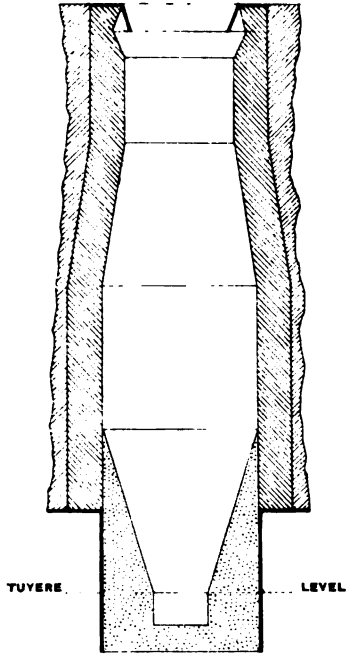
FIG. 1.



-FURNACE AT SIMSK WORKS.

Scale, 15 Feet to 1 Inch.

FIG. 2.



No. 1 BLAST-FURNACE
AT BARANCHINSK WORKS.

REFERENCE.

SAND AND CLAY, RAMMED.

INNER LINING.

OUTER WALL.

Scale, 1 Foot to 1 Inch.

BURNER FOR NAPHTHA RESIDUE MINIARSK PUDDLING-FURNACE.

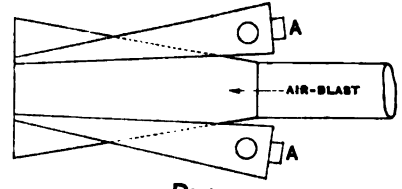
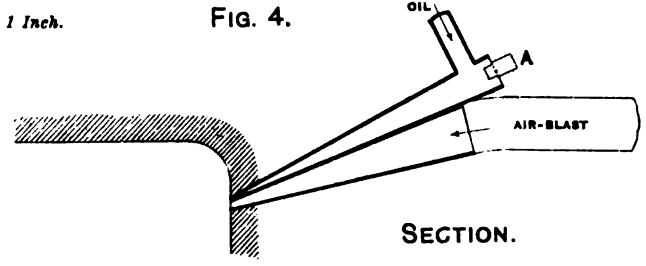


FIG. 3.

PLAN.

A A ARE PRICKER-HOLES FOR CLEARING OIL-JETS, WITH PLUGS.

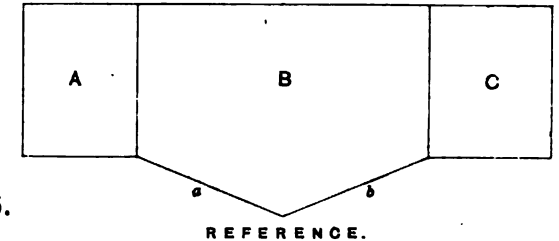
FIG. 4.



SECTION.

DIAGRAMMATIC PLAN OF DOUBLE PUDDLING-FURNACE AT CHUSOVAIA WORKS.

FIG. 5.



REFERENCE.

A—FIREPLACE. B—FURNACE-BODY. C—HEATING-STOVE.
a, b WORKING-DOORS FOR TWO PUDDLERS.

And.ᵛ Reid & Compʸ Lᵗᵈ Newcastle on Tyne.

similar cases elsewhere, and in other countries the forests have receded so fast from the furnaces as to cause, on this account alone, the extinction of the latter.

The Urals will, for many years to come, be able to supply the extensive regions of Siberia with charcoal iron cheaper than iron made with mineral fuel can be imported; as communications improve, however, this advantage will constantly diminish. On the other hand, much of the internal traffic of Russia is carried by the Volga and its affluents; a considerable portion of the iron region of the Urals is drained by the rivers Chusovaia and Bielaia, as well as by the Kama, into which the two former flow, and all these rivers are navigable. Hence the iron produced in this section of the Urals has only to be carried down stream, whilst that of its chief competitor, the Donetz basin, has to be transported up stream. Moreover, the Urals have the advantage of relative nearness and water communication to Nishni-Novgorod, the great central mart of Russia; as long as this locality retains its commercial supremacy—which shows, however, already some signs of declining—the Urals can send iron to it more readily than any other iron-producing region. It would seem, therefore, that the iron industry is likely to survive many years yet in the Urals, although this district is fast losing, if it has not indeed already lost, the premier position which it once held amongst the iron-producers of the Russian Empire.

Mr. C. H. Stevenson said that Prof. Louis had read a very useful paper, and he had pleasure in proposing a vote of thanks to the writer.

Dr. P. P. Bedson, in seconding the vote of thanks, said that he was very much interested in some of the points raised, especially the survival of the use of charcoal in the production of iron, which had practically disappeared in this country. Another point was the use of chrome-iron ore in forming the beds of open-hearth furnaces, and this called to mind some experiments which Sir Lowthian Bell made in Cleveland with the view of de-phosphorizing the steel by means of chrome-ironstone hearths in the furnaces.

Prof. Louis acknowledged the vote of thanks.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 11TH, 1897.

MR. R. R. SIMPSON IN THE CHAIR.

The CHAIRMAN presented the President's prizes to the writers of the following papers :—

"Cornish Methods of Mine-timbering." By Mr. G. P. Chaplin.
"Economical Combustion of Coal for Steam-raising Purposes." By Mr. T. E. Parrington.

DISCUSSION UPON MR. T. E. PARRINGTON'S PAPER ON "ECONOMICAL COMBUSTION OF COAL FOR STEAM-RAISING PURPOSES."*

Mr. R. R. SIMPSON wrote that although agreeing in the conclusions which Mr. Parrington had drawn in his interesting paper, he might mention one or two points in which he appeared to be inaccurate. In the first place, the total products of the analysis of the coal used in the experiments was given as 87·6 per cent., leaving 12·4 per cent. unaccounted for—this seems rather too large an allowance for sulphur and ash.

Judging from the quantity of air supplied in the experiments (15 to 20 pounds per pound of coal), one is inclined to suspect that a considerable amount of incomplete combustion would take place, resulting in the formation of carbon monoxide and consequent loss of heat. The more usual allowance of air is about 18 lbs. for forced-draught, and 24 lbs. for ordinary chimney-draught.

In estimating the number of thermal units derived by the combustion of the hydrogen contained in the coal, Mr. Parrington has omitted to

* *Trans. Fed. Inst.*, vol. xiii., page 384.

make allowance for the amount of heat required to maintain the product of combustion (water) in a state of vapour—on applying this correction, the value 62,032 becomes reduced to 52,490 thermal units. The amount of heat generated by the combustion of the sulphur in the coal is also omitted; this is perhaps hardly appreciable, but it may be mentioned that 1 pound of sulphur in burning evolves 3,996 thermal units.

In calculating the saving of coal effected by the increase in the number of boilers, it seems hardly correct to fix the selling price of the coal saved at 6s. per ton. Presuming that these experiments refer to colliery plant, an allowance of 4s. per ton would perhaps be nearer the mark, as it must be remembered that the coal used for firing the boilers at most collieries is very inferior.

The cost of the extra labour entailed by the use of the additional boiler is omitted in the calculations in the paper.

A much greater waste of fuel than that dealt with by Mr. Parrington occurs at the majority of collieries, owing to the use of low steam-pressures, a common working pressure being about 60 pounds per square inch (absolute). A glance at Dr. Regnault's tables shows that the total heat, from 32° Fahr. contained in 1 pound of steam at 60 pounds pressure (absolute) is 1170·7 units; whilst for steam at 150 pounds pressure (absolute) the total heat is 1190·7 units. Thus for a more than doubled steam-pressure, the extra amount of heat required is under 2 per cent. of the whole amount. In other words, by doubling the steam-pressure the same amount of energy can be developed by using only one half of the fuel.

Mr. JOHN CADMAN read the following "Notes on Rearer Workings":—

NOTES ON REARER WORKINGS.

By JOHN CADMAN.

The following notes are intended to describe the methods employed in the working of the coal-seams lying on the western side of the North Staffordshire coal-field.

The inclination of the coal-seams in some parts of that district is very considerable, not only appearing in a vertical position but exceeding it, so that the floor of the seam becomes the roof. Numerous seams of workable coal occur, and the following is a section in the lower measures :—

Name of Coal-seam.	Average Thickness. Feet.	Approximate distance between Seams. Feet.
Single Four Feet	4½ to 5 ...	... 42
Single Two Feet	2 ,, 3½ ...	... 27
Single Five Feet	4½ ...	... 72
Ragman	3 to 3½ ...	... 21
*Rough Seven Feet	7 ...	... 12
*Hams	4 ...	... 222
Ten Feet	7 to 8½ ...	... 54
Top Two Row	2½ ,, 3 ...	... 39
Bottom Two Row	2½ ,, 3 ...	... 306
Seven Feet Bambury	6 ,, 7½ ...	... 111
Eight Feet Bambury	6 ,, 7½ ...	... 153
Bullhurst	7½ ,, 14	

* The Rough Seven Feet and Hams coal-seams in some places occur almost as one seam, with about 6 to 12 inches of bass parting between them.

The coal-seams have almost every variety of roof and floor, and are also very much cut up by faults, whose displacements vary from a few inches to 2,000 feet.

Seams having a higher gradient than 45 degrees are called "rearers," and it is found impracticable to work such seams by the longwall system.

Mode of Working.—A modification of the pillar-and-stall system is usually adopted. The breadth of coal, recovered at one time, generally varies from 350 to 750 feet, that is the distance from the bottom level to the old workings above. This recovery is made by sinking the pit to a depth estimated from the area required and the inclination of the seam,

and then driving a crut or cross-measures drift, intersecting the measures at right angles (Fig. 1, Plate XX.). The breadth being recovered, levels are driven out on either side to within 180 feet of the boundary, and at this point three heads are driven to the full rise of the seam, viz., a cage or brake-dip *A*, usually used as an intake-airway, a return-air-dip *C*, and a travelling-dip *E*, which contains steps or ladders.

The dips and crosscuts are usually driven about 36 feet apart. These dips are driven to within 30 feet of the old workings laying above, and a series of levels are then driven out each way for 180 feet, the top ones being driven in advance of the lower. When the top levels are driven to their distance, thurlings are driven up to the gob, and the rib of coal is then drifted back or worked out to the dip *A*.

When the first drift has advanced 30 or 35 feet, the next drift below is opened, and so on down the dip, but it is rare that more than three drifts on either side are working together (Fig. 2, Plate XX.). The two drifts on the same level are wholly worked out together so as to enable the brake-wheel to be lowered to the next level below. If the roof be bad, pillars of coal, about 15 feet wide, are left on either side of the dip, until the brake-wheel is lowered. These pillars are then taken out, the coal slipping into a screen at the side of the brake-wheel from which the coal is loaded. A breadth of 360 feet of coal is worked from a set of dips, the cage-dip being placed in the centre of the breadth.

Drifting.—There are two principal ways in vogue of drifting or of removal of the pillars of coal. In the first of these, the coal-face is kept at an angle of about 45 degrees to the level, which is (about) the line of cleavage. There are always 4 or 5 rows of props standing in a drift, and a rib of coal of about 3 feet in average thickness is left at the top of the drift to keep the gob from slipping down and filling up the drift (Figs. 2 and 3, Plate XX.).* As the drift advances, the last row or two of props are drawn, and as soon as the upper two or three props supporting the rib are knocked out the gob slips down into the open drift. A wooden mallet with a long handle is used to knock out the top props.

When the coal is fairly strong, the gob may not slip when the top props are knocked out, and a "bodger" is then used; it is 10 or 15 feet long, and consists of a wooden bar with a steel spike, about 1 foot long. The workman stands behind some timber near the drift-face, and bodges or works out the bottom of the rib until the gob forces its way through.

Frequently the seam is more easily worked in one direction, owing to

* This method of drifting was illustrated by a model.

the prevalance of cleats or slips, and as the coal has to be drifted back to the dips from two opposite directions, one of these will be the least favourable one for getting the coal. To obviate this disadvantage, drifting is generally done in the same direction as on the other side of the dips, but from a fast end, or from a thurling, for a distance of about 30 feet; when this distance is worked out, a new drift is started 30 feet nearer the dips (Fig. 2, Plate XX.). This is called a "back-way" drift, while the opposite or an ordinary drift is called a "face-way" drift.

In the thicker seams, the coal is not holed to any extent in drifting, being wedged in fiery mines, and blown down by explosives to the slips in non-fiery mines. The collier works on a scaffold (Fig. 4, Plate XX.), formed either by laying posts lengthways between props set 4 or 5 feet apart, and allowing small coal to level up, or by spiking a rail or batten across two props and placing boards from the rail to the floor of the seam.

The second method of drifting is to shoot the gob and allow it to entirely fill up the drift, a breasting from 6 to 9 feet wide is then taken up bank, as shown in Fig. 5 (Plate XX.) In this case, the workmen can stand on the gob to work, and avoid the use of scaffolding to a great extent.

When the breasting is within 3 feet of the old workings above, a shot is put in the rib, which blows through the rib and allows the gob to slip.

This method is found to be rather more expensive than the first method, and it cannot be employed with safety in a fiery mine owing to the risks in blasting the rib, or what is technically known as "shooting the gob."

As some of the coal-seams are very liable to spontaneous combustion (especially the Bullhurst), great care has to be observed in their working, because these fires frequently occur in seams producing much fire-damp and very dusty, so that in addition to the fire itself there is a risk of serious explosion.

As a preventative to spontaneous combustion, the following method of working the coal is sometimes adopted. The gob is allowed to fill with gas, and as each pillar of coal is worked out on the rise, the next level below becomes the return airway and the gob above becomes charged with gas, only allowing sufficient ventilation to pass so as to keep the edges of the gob and working-places free from gas.

Another method frequently adopted is to work the coal out in panels, leaving a solid rib of coal about 60 feet wide between each panel, con-

taining about 1,080 square feet. As each panel becomes exhausted, they are entirely built off, the gob being thus hermetically sealed. Of course, the thickness of the rib entirely depends upon the nature of the coal-seam.

The Cage-dip is the road from the higher working-levels to the lower main level or haulage-road. Cage-dips are fitted up in two ways, either with two cages, or with one cage and one counterbalance.

The double cage-dip is usually of a permanent kind, generally adopted when the coal to be worked out requires to be braked more than once, owing to the great breadth ; and until the top breadth is worked out, two cages are used.

The cage and counterbalance is arranged so that the counterbalance either runs by the side of the cage or underneath it. The gauge of the cage-wheels varies from 3 to 4 feet and that of the counterbalance from 1½ to 2 feet. The dips are usually laid with bridge-rails placed on battens. The sleepers are fastened either by being sunk into the warrant or thill, and placed above two props one on either side, or by being spiked (spike-holes having been drilled into the floor for this purpose). The cage (Figs. 6 and 7, Plate XX.) consists of a wooden frame and two pairs of wheels. The waggon is received on rails, and the requisite catches are provided to prevent the waggon from slipping off the cage. The weight varies from 10 to 12 cwts. One cage is capable of running from 100 to 120 tons of coal down a dip, 300 feet in length, in a shift of 8 hours. The counter-balance or dummy is a low weight-carriage on wheels, and is fastened to the rope by glands, so as to allow of the length of the rope being adjusted from time to time.

The brake-wheel used in cage-dips is shown in Figs. 8 and 9, (Plate XX.). A wooden segment or felloe block *A*, clips one-third round the wheel, and is fastened to an iron brake-strap *B B*, which is connected to the brake-lever *C*. The rope, usually ½ to ⅝ inch in diameter, is wrapped 1½ times round the wheel, which is 4 feet in diameter. The wheel is generally set on the dip, and is only placed vertically when the dummy or counter-balance runs underneath the cage.

Frequently in the double cage-dip system, a special form of brake is used, consisting of two wheels, having three rope-grooves in the upper wheel and two in the lower one (Figs. 10 and 11, Plate XX.). The rope thus makes three half-turns round the upper and two half-turns round the lower wheel. This arrangement is very effective, the friction produced by the contact of the rope and the wheel, 2½ times its circumference

instead of 1½ times, as in the former wheel, being sufficient to hold a great weight. In order to allow the loads to run on and off the cage from intermediate levels, short rails are thrown across, called "tab rails." These rails are usually hinged to the sleepers, and can be turned back when not in use.

In conclusion, the writer might add that dips of from 65 to 90 degrees are found easiest to work, as the gob shoots down regularly and fills up most of the space, and so protects the roof round about the coal-face. Naturally, in steep workings, the gob has to be carefully watched, and the workmen have to be constantly on the alert. In some of these coal-seams the workmen have occasionally to resort to speedy flight, owing to a sudden total or partial shooting of the gob.

The CHAIRMAN said that he was particularly interested in this paper, because, during the summer, he had the pleasure of going down some of the mines that the writer had described, and he could testify to the dangers of mining in that district. A man who worked in the Staffordshire mines would be able to work in any mine in the world. He proposed a vote of thanks to Mr. Cadman for his interesting paper.

The motion was unanimously adopted.

Mr. CADMAN exhibited and explained a model illustrative of his paper.

FIG. 8.—PLAN.

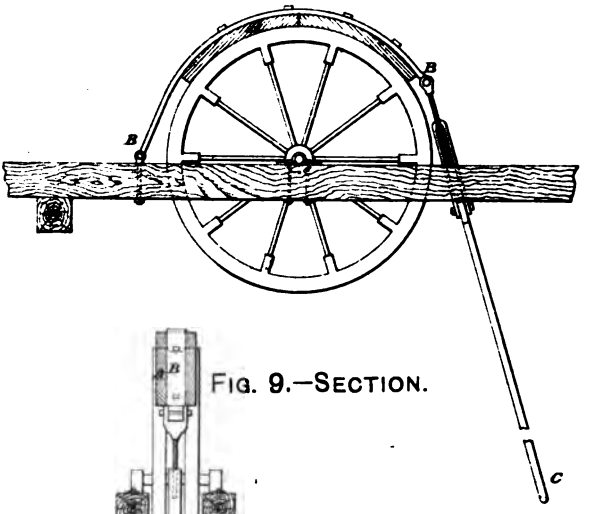
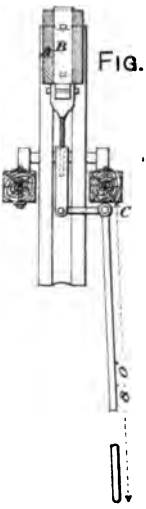


FIG. 9.—SECTION.



Scale, 3 Feet to 1 Inch.

FIG. 10.—PLAN.

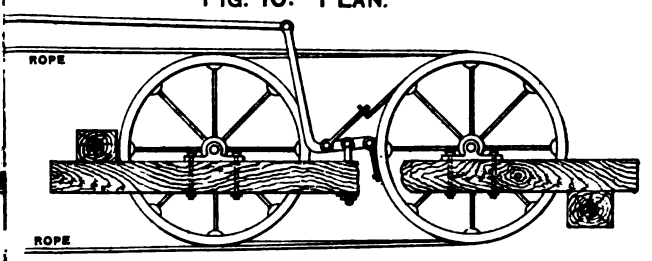
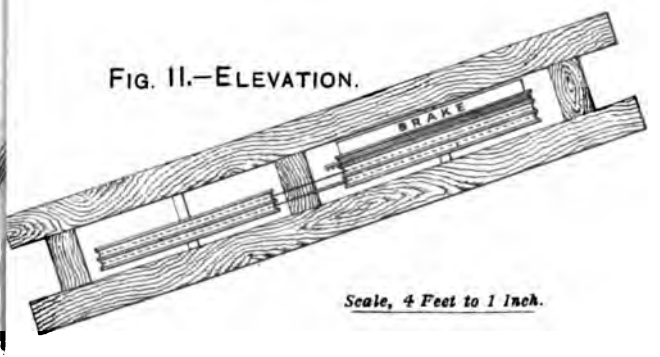


FIG. 11.—ELEVATION.



Scale, 4 Feet to 1 Inch.

DISCUSSION UPON MR. E. F. MELLY'S PAPER ON THE "USE OF STEEL GIRDERS AND PROPS IN COAL-MINES."*

The PRESIDENT remarked that he could speak favourably of steel girders and props. He had used them successfully at the Cannock and Rugeley collieries, where they had proved most satisfactory.

Mr. W. WARDLE (West Cannock) stated that he had adopted the use of steel girders with success. During the last twenty years, he had used some hundreds of tons of girders, and only three had been broken. He had always strongly recommended the adoption of steel girders in preference to timber.

THE EXPLOSIVES IN COAL-MINES ORDER, 1897.

The PRESIDENT directed the attention of members to the Explosives in Coal-Mines Order, 1897, and stated that it would come into operation on January 1st, 1898. As the members all knew, permitted explosives were then only to be allowed subject to certain conditions. The order would add to the cost of getting coal, but it had to be faced. He had tried ammonite, bellite, and carbonite, and took every care to submit these, as near as possible, to the same experimental conditions, and tested them in the same kind of rock. He was pleased with bellite, he found that carbonite made more fumes than bellite, but the explosive he liked best was ammonite. Further, the fumes were less from ammonite, and the work done by it was most excellent. Carbonite did not seem to destroy the coal, and he felt bound to admit that the first shot with ammonite did not work so well as it ought. In working out the comparative costs of the three explosives, he found very little difference.

Mr. WARDLE said it was evident that mining engineers would have to consider at once which of the explosives they would adopt. Up to the present time, he had used carbonite in the West Cannock colliery, Shallow coal-seam, but he was going to make experiments with ammonite and bellite, and afterwards he would decide which of the three explosives he would adopt.

The meeting then closed.

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* *Trans. Fed. Inst.*, vol. xiii., page 277.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS

AND

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

JOINT MEETING,

HELD IN THE ROOMS OF THE LITERARY AND PHILOSOPHICAL SOCIETY, SHEFFIELD, OCTOBER 26TH, 1897.

MR. G. BLAKE WALKER IN THE CHAIR.

The following gentlemen were elected to the Chesterfield Institution :—

MEMBER—

Mr. BATHGATE COMB, Road Surveyor to the Derby County Council, Highfield House, Ashover, Chesterfield.

ASSOCIATE MEMBER—

Mr. ARTHUR THOMAS METCALF JOHNSON, Retired Civil Servant, 109, Calabria Road, Highbury, London, N.

STUDENT—

Mr. FREDERICK HOWARD BRIGGS, Mining Student, Galley Farm, Atherstone.

The following gentlemen were elected to the Midland Institute :—

MEMBERS—

Mr. HARRY WARDELL, Colliery Manager, Featherstone Main Colliery, Wakefield.

Mr. ARTHUR HORSFIELD, Colliery Manager, Hughesoffka, South Russia.

Mr. ERNEST DOUGLAS, General Manager and Agent, Pemberton Colliery, near Wigan.

Mr. T. G. LEES (Clifton Colliery, Nottingham) read the following paper on "Internal Corrosion of Wire Ropes" :—

INTERNAL CORROSION OF WIRE ROPES.

By THOS. G. LEES.

The question of corrosion of wire ropes is by no means a new one, and at many collieries this trouble has been successfully dealt with, but there may be other collieries having wet shafts where the difficulty has not yet been overcome. In explaining the methods which the writer would suggest in dealing with this matter, he may perhaps touch upon one or two points of an elementary character which are wellknown and practised by many colliery managers. These remarks may, nevertheless, be acceptable to those members who may not have given the subject the attention it deserves. At the same time, the writer does not claim to teach anything new or original respecting the management of wire ropes, and would simply place before the members a short account of his experience and the practice in dealing with them, not only at Clifton colliery, but at many collieries and mines having winding-ropes working in wet shafts or exposed to the action of steam or a mixture of steam and furnace-gases.

The term "corrosion," as applied to wire ropes, will be understood to mean a gradual eating away of the substance of the wire, the metal being changed or converted into oxide of iron, etc. This corrosion has sometimes been mistaken for abrasion, but it is quite a distinct action and cannot reasonably be mistaken for it.

There are various stages of corrosion, beginning with only the slightest pitting (so fine as scarcely to be perceptible to the naked eye), which if disregarded will slowly become more pronounced, the wire being indented and grooved, and consequently very much reduced in strength, and finally rusted or oxidized throughout. When once the bright surface or skin of a wire is pitted, it has been found that a great part of the strength of that wire has been lost, and on testing it will break short. This peculiar action has in the past not been fully recognized, and in some instances the cause has been thought to be due to the use of inferior quality of wire.

The writer does not intend to convey the idea that all wire ropes must necessarily be corroded under all circumstances, and these remarks only refer to ropes working under unfavourable conditions, and subject to the action of moisture only, either as steam or water, or it may be with ace-gases in addition.

The waters that find their way into the shafts of collieries differ very greatly in their chemical composition, some being comparatively harmless, others containing elements of a very corrosive nature, and the best of waters (in conjunction with the action of air) may cause oxidation or corrosion to take place, if allowed to act upon the bare wires of a rope for any length of time.

At Clifton colliery, Nottinghamshire, the water is drawn from the sump every night by means of barrels fixed inside the cages. An analysis of this water was made a few years ago by Dr. E. B. Truman, late analyst for Nottingham, as follows :—

	Per 100,000 Parts.	Grains per Gallon.	Per Cent.
Organic carbon	0·49	?	?
,, nitrogen	0·061	?	?
Nitrogen: as nitrates and nitrites ...	0·094	?	?
Ammonia	0·002	?	?
Total nitrogen	0·1758	?	?
Chlorine	84·700	59·29	0·084
Chloride of sodium	140·36	98·25	0·140
Total solids	213	149·10	0·213

Permanent hardness, 12·17.

This water being so strongly impregnated with common salt (nearly 100 grains per gallon) accounts, the writer thinks, for its action upon the ordinary wires of the ropes used in years past.

There are three points in a winding-rope where it has been found from experience that corrosion usually takes place. The first is at the cap-end of the rope; the second where the ropes rest on the pulleys when the cages are at the top and bottom of the pit respectively; and the third point is on the underlapping rope at the drum. At the second and third of these points, the strands of the ropes are opened more or less, due to the bending over the pulleys and under the drum, thus allowing water to enter more easily at these points than at other parts of the rope. But it is at the cap-end that the wires suffer most, and this is probably due to the fact that every time the cages settle on the props or keeps, at the pit-top and at the pit-bottom, a certain amount of slack rope allows freedom of motion for the wires to untwist and bend, and thus the strands open somewhat and allow the water to percolate into the inside of the rope.

If all the failures of winding-ropes could be ascertained, it would be found that by far the greater number occur within a few feet of the cap from a variety of causes, and not necessarily from corrosion alone. Owing to many of the accidents causing no loss of life or personal injury, official records are not obtainable. In the opinion of the writer, the only practical way of dealing with this part of the rope is periodically to cut off a few feet and recap the rope. Special rule No. 105 for this

district says that it shall be the duty of the enginewright to recap the ropes "as often as necessary." This leaves it to the discretion of the manager and enginewright to say how often it is necessary and what interval of time shall elapse between successive recappings of the rope. Opinions vary as to this, and the writer suggests 3 or 4 months as being sufficiently long for a winding-rope to run without removing the cap; and in the case of sinking-ropes the interval should not exceed 2 months.

It is hardly necessary to enumerate to colliery managers all the advantages which are attached to systematic recapping of winding-ropes, but it would be well to mention the two most important. Firstly, by cutting off a few feet of the rope, the condition of the inside strands can be thoroughly examined and the wires tested, and if found to be in good and safe working order, the cap may be put on again; secondly, the rope being let out from the drum to replace the length cut off, changes the position on the pulleys where the greatest strain has to be taken at the lift out of the pit-bottom.

A matter of importance in connexion with recapping is the length of rope to be cut off. It is of little use to merely cut off the cap and to put it on again, as unless sufficient length of rope is cut off the various weak points previously mentioned are not changed or moved forward, as it were, but remain practically in their original position. It is advisable under ordinary circumstances to cut off about 12 feet from each rope, and it has been the practice at Clifton colliery to only let out one rope from the drum alternately at each recapping.

The operation simply is: One rope, after being recapped, is lowered by the engineman and attached to the cage, and this causes the other rope to be 24 feet too short, so that it has to be let out from the spare rope provided and kept coiled around the inside of the drum. Thus each rope is altered 12 and 24 feet alternately at each recapping. Sufficient spare rope is allowed for in ordering a new rope to provide for recapping, in addition to the two rounds of rope which must be left on the drum in accordance with special rule No. 117.

In sinking shafts, it may be an advantage to cut off a greater length than in ordinary cases of winding-ropes, as the ropes are subject to more bending and twisting near the cap-end, and to varying strains in addition to the corrosive action of the water.

In order to preserve the ropes and to act as a lubricant, oil or grease is generally used at most collieries, and if a good quality of lubricant is used, perfectly free from acid, the results may be satisfactory, but only under favourable conditions. Should the ropes be working in a wet shaft, the water of which contains anything of a corrosive nature, it has

become generally acknowledged by engineers who have had such waters to deal with, that oil or grease, however carefully applied, will not keep the ropes from being corroded, and that the water will find its way, after a time, to the inside and do serious damage to the wires, while to all outward appearance the rope may be in good order. This apparently safe condition of the rope on the outside has been the means of frequently deceiving the person making the inspection, and the writer is afraid that, unless steps are taken to get at the root of the evil, accidents from internal corrosion of wire ropes will continue to occur in the future.

In a paper read before the Chesterfield and Midland Counties Institution of Engineers by Mr. P. M. Chester,* on "Colliery Winding-ropes and their Attachments," the following paragraph appears :—

> Greasing frequently is of great importance: it prevents corrosion, due to the action of the atmosphere and furnace-gases. None but pure and well manufactured grease should be applied, as that containing any acid is most destructive ; it should be liquid, and carefully forced in with brushes. The author has seen a winding-rope [with a hemp centre] which had been in a moderately dry shaft, and greased every fortnight: when taken off and cut, the wires inside were found rotten, owing to the grease not having penetrated to the centre.

It is quite impossible, by any of the usual systems of outward inspection such as are practised at many collieries, to discover the condition of the rope internally, and it does not appear reasonable to simply rely upon such superficial examinations as passing the rope daily through the hands. This method may indicate whether there are any broken wires on the outside, but cannot reveal the condition of the inside of the rope.

The general practice of most rope-makers, unless otherwise instructed, is to build up the ropes with a hempen core, and this fact, in many cases when working in a wet shaft, helped to shorten the life of the rope, as the hemp absorbs and retains the moisture, which acts upon the internal wires and causes corrosion.

During the discussion which followed Mr. Chester's paper, before referred to, Mr. A. H. Stokes said :—

> Then the author (Mr. Chester) made a remark that ropes "were best made with hempen centres only." . . . He (Mr. Stokes) held in his hand a specimen of Lang's patent rope, a very strong rope for the work it had to do, yet the hempen core had so absorbed moisture, that the inside of the rope was so corroded that it broke whilst at work ! He was not at liberty to mention where, but the manager was a gentleman who would not put any but the best material on. It broke a few yards from the cap, and the cage went to the bottom. . . . . The outward appearance of the rope was such as to deceive all who examined it, being very little worn, in fact it was difficult to detect any signs of wear, yet the inside of the rope was eaten away by corrosion to such an extent that it broke whilst winding. The rope had only been at work about 18 months in a dry shaft, and had been well and frequently greased. The cause of failure was certainly corrosion.†

* *Trans.*, vol. xiii., page 386. † *Trans. Chester. Inst.*, vol. xiv., page 11.

Plain wire cores have been substituted for hemp with very little better results; the centres have also been painted with a special preparation to preserve them, but this has not been a success so far as the writer is aware.

At No. 1 shaft of Clifton colliery, where water is drawn, flat wire ropes were in use up to 1880, and the average life of the last 18 ropes was only 9 months. Owing to the heavy expense and short life of these ropes, the manager decided to change the drums and line the pulleys, in order to adopt the use of round ropes. The first pair of ropes were put on in June, 1880, 4½ inches in circumference, and made of improved patent crucible steel wires with a hempen core. These ropes worked 1 year and 9 months and were recapped 4 times; when taken off, the internal wires were found to be very seriously corroded, owing to the hempen core having absorbed moisture, although the ropes had been well and regularly greased once a week. The condition of the ropes was so bad that the manager wrote to the makers for advice, and they (as a result of similar experiences gained at other collieries having bad water to contend with) recommended that the wires should be galvanized. A pair of ropes were obtained, made of improved patent crucible steel, with galvanized wires, and with a galvanized wire core in the centre of the rope. By recapping these ropes at intervals of about 3 months they lasted 3 years, and were quite free from any corrosion when taken off, the wires being clean and bright inside, and the galvanizing intact, except at those points where the wires crossed each other inside the strands, and on the outside wires which were worn bright and flattened somewhat by rubbing on the pulleys. Where this abrasion occurred the grease used as a lubricant was sufficient to keep the surface of the wires bright and clean.

After this experience, galvanized wire ropes have been used up to the present time (about 15 years) at both shafts: the average life of the ropes at the wet shaft being 3 years and at the upcast shaft 4 years; and those now at work are the fifth pair at the wet shaft, and have been in use for 2½ years. The condition of the ropes after being taken off was so satisfactory that a pair of old ropes are kept in stock ready to put on again temporarily in a case of emergency.

In testing, recently, the last rope taken off the wet shaft (2½ years ago), and which had lain on the pit-bank exposed to the weather, the writer found that the wires, of No. 10 Birmingham wire-gauge, broke at a strain of 2,142 pounds or 19⅛ cwts; in the torsion-test they broke at a strain of 10 or 11 revolutions in 8 inches lengths, and stood 7 and 8 bends over an angle of 180 degrees when fixed in a vice, and then broke. These wires

were taken from the cap-end, and the ropes would no doubt have been perfectly safe to work for a longer period. The ropes at work at the present time were recapped on July 6th, 1897, and the wires tested. The breaking-strain of the wires of No. 10 Birmingham wire-gauge was found to be 2,160 pounds or 19⅓ cwts; in testing for torsion they broke at from 12 to 20 revolutions in 8 inches lengths, and bent 7 times before breaking over an angle of 180 degrees when fixed in a vice.

The writer has frequently been asked whether galvanizing does not seriously injure the wires, but his experience has fully proved that practically no deterioration takes place if the galvanizing has been properly done. Some prejudice has existed in the past against the use of galvanized wire for ropes amongst mining engineers, but it must have been only on the part of those who have had no experience in their use. The writer was informed by a well-known firm of rope-makers that it was as important that the galvanizing should be done carefully and by the best process as that the wire itself should be properly drawn, and that in either process, if carelessly or improperly done, the wire might be spoilt. The following tests were made by the writer with new wires supplied by the makers of the winding-ropes, the wires being of the same quality and thickness (improved patent crucible steel, and No. 10 Birmingham wire-gauge), but one portion plain and the other galvanized; the object of the tests being to find out what effect, if any, the galvanizing had on the strength of the wires. The ultimate strengths in these tests cannot be compared with those of the previous tests mentioned, as, although of the same diameter of wire, the quality might not be identical with the ropes supplied previously :—

Description of Wire.	Torsion in 8 Inches. Revolutions.	Breaking Strain. Pounds.	Bends at Right Angles over 180 Degs. Bends.
Plain	24	2,310	7
,,	32	2,200	8
,,	25	2,366	7
,,	33	2,086	8
,,	23	2,190	7
,,	27	2,142	7
Mean	27	2,215	7
Galvanized	26	2,142	7
,,	24	2,048	8
,,	29	2,240	7
,,	24	2,360	7
,,	23	2,254	7
,,	27	2,086	8
Mean	25	2,178	7

It will be seen from the foregoing table that the falling off in strength in the galvanized wire is so slight as to be practically of little importance, and no uneasiness need be felt on that score when ordering a galvanized rope.

As stated previously, no credit is claimed by the manager of Clifton colliery in any way for the results obtained by using galvanized wire ropes, as such ropes have been in use for the last 20 years at several collieries; but the writer has frequently conversed with colliery managers and others who were unaware of the fact that winding-ropes could safely be galvanized, and were surprised that such good results could be obtained. It would therefore be very interesting to know the opinions of other members who have had experience with such ropes.

In the case of winding-ropes, upon which the lives of so many men and boys daily depend, it is of the utmost importance that every precaution should be taken to prevent any mishap. It is not sufficient that a rope shall be of the best material, unless adequate means are taken to keep it in safe working order. As the writer has mentioned previously, oil and grease may be, and are, in many cases quite sufficient when properly applied, particularly when the ropes are first put on, to prevent any serious mischief from corrosion; but if water has to be contended with, especially bad water, the writer has found that oil is of very little use in preventing corrosion.

The question of cost ought not to stand in the way of employing the best winding-ropes procurable for use in winding-shafts, and the first cost of a rope, even if a trifle higher, is of small moment, if extra security and a longer life be gained by the use of such a rope. In fact, the writer believes that it is more economical to pay the cost of galvanizing the wires of ropes working under ordinary conditions. The extra cost of galvanizing a winding-rope 4½ inches in circumference is about 5s. per cwt. The writer's meaning will be made clear from the following example:—Suppose a crucible-steel wire rope, 500 yards long, 4½ inches in circumference, weighing about 45 cwts., and costing 35s. per cwt., made of plain wires, the total cost will be £78 15s., and the rope will probably last 2 years, thus costing £39 7s. 6d. per year; a galvanized wire rope of the same strength at 40s. per cwt. will cost £90, and may safely be assumed to last 6 months longer than the rope with plain wires, and would in such case cost £36 per annum, showing a saving of £3 7s. 6d. per annum, or £8 8s. 9d. per rope. This is a very low estimate as to the economy of using galvanized wire ropes, as their life might be lengthened 50 per cent. and upwards.

The following is Mr. J. L. Hedley's account of a fatal accident due to a winding-rope breaking through corrosion :—

On the 23rd October, a fatal accident occurred to Wm. Graham, joiner at the Buckhill colliery, Cumberland, under the following circumstances :—He was engaged in the pumping-shaft looking for a leakage in a column of water-pipes, and had been slowly raised for a distance of about 14 fathoms, when the rope suddenly broke, and he was precipitated to the bottom, and instantly killed. There was no evidence to show that the cage in which the deceased was riding had met with any obstruction in the shaft, but an inspection of the rope showed that at the point of fracture it was corroded completely through, a fact not to be wondered at when the history of the rope was told at the inquest.

The rope was of steel wire, 1 inch in diameter, and had been in use for about 5 years. It was at first used for raising coals from the bottom to an "eye" 19 fathoms up the shaft, beyond which the cage did not pass ; but when, 3 years ago, coal-winding ceased it was left hanging in the shaft, not only to enable the joiner to examine the pumps, but to raise the men in case of an accident at the other shaft. During these 3 years the rope had never been properly examined, nor had it been oiled or greased ; although on the 16th March the whole of the rope was on the drum. On that occasion the engineer, who had been in charge of the machinery for 10 months, examined the rope for broken wires as it was lowered down the pit, but failed to detect any. Whether this rope was one which could be said to be in actual use, and which consequently should have been examined every 24 hours, or not, it is certain that common prudence should have dictated to any manager or engineer the necessity, when men's lives depend upon a rope, of making periodical inspections, and especially where a shaft is wet of taking every care to protect it from injury. . . . .

It is only fair to state that tests were made in my presence with some of the wires taken from what I considered to be the worst part of the broken rope, with the result that its original estimated breaking-strain of 17 tons was shown to have been reduced to one of 10 tons ; and further that, as far as I could ascertain, the excessive corrosion was confined to the point of fracture, which, as the rope usually hung in the shaft, would be in the open air about 7 feet below the pulley.*

The foregoing description requires no comment from the writer, but he would suggest that had galvanized wires been used in the rope mentioned the accident would in all probability not have happened.

Hauling-ropes may be galvanized with advantage, as many colliery managers can testify who have used them, especially where the roadways are wet, but even where the roads are dry it is found that the ropes have fewer broken wires and last longer. It is also an important matter to have a wire core in haulage-ropes working on the endless-rope system for two reasons :—When a new rope is put on with a hempen core, if the load is a heavy one, great trouble is experienced by the rope stretching and thus lessening in diameter, so that slipping takes place when certain classes of clips are used for attaching the trams or tubs to the rope.

* *Report of J. L. Hedley, Esq., H.M. Inspector of Mines for the Newcastle District for the Year 1894*, page 9.

With a wire core the rope maintains its original diameter, the lengthening of the rope is very much less, and there is very little trouble caused by the clips slipping.

In using wire conductors for shafts, subject to water, steam, or hot gases, it is well worth considering whether it would not be economical to galvanize them, and the writer may mention that they have been adopted with every satisfaction at Clifton colliery.

In conclusion, the writer suggests that as the corrosion of wire ropes is a most important subject, the question of how best to keep winding-ropes in the safest condition for raising and lowering workmen often from great depths should be seriously studied, and if one method be found to be better than another, it should be made known to those who have not practised that method in the past.

Mr. M. H. MILLS (Mansfield) said that the safety of their ropes was one of the most important considerations to be borne in mind by colliery engineers. Everyone had had difficulties, and many had had ropes running for a considerable time, and found the ropes perfectly good when they had been cut and re-capped. No doubt Mr. Lees was right in advising constant re-capping of the ropes, though it was questionable whether the length recommended to be cut off and the frequency of re-capping were not both rather more than was necessary. The use of galvanized wire was, to his mind, an advantage for winding-ropes, but he was doubtful as to the use of solid core for haulage-ropes—whether it would be sufficiently pliant to go round sharp curves.

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) observed that Mr. Lees' paper opened up a very important subject in colliery management. He would like to ask whether the elasticity of the material used for galvanizing was equal to the elasticity of the wires composing the rope, and, if not, whether there would not be an unequal strain. If the galvanized coating cracked, water would get through and attack the steel wire, and the constant bending of the wires over the pulley-wheel would have a tendency to produce cracks in the material used for galvanizing. He would suggest that, before the statement was accepted that a galvanized rope was better than an ordinary wire rope, some tests should be made as to what would be the effect of bad water upon ropes that had undergone the galvanizing process, both as regarded tension and twisting.

The re-capping of winding-ropes was a subject deserving serious consideration. Mr. Lees stated that he would cut off a few feet—how many feet? When the rope stood on the pulley-wheel with a load attached, the strands resting on the tread of the wheel had a tendency to open, but directly they were relieved of the load the strands had a tendency to close, and such continuous opening and closing in wet weather would squeeze water in or grease out, and *vice versâ*. If a few feet only of the rope were cut off when re-capping, the place which had been undergoing the deterioration on the pulley-wheel was then removed forward between the pulley-wheel and the top of the shaft. Winding was resumed for, say, another four months, and re-capping again took place; but the part of the rope which was first resting on the pulley-wheel was not cut out, and thus the rope might be re-capped a number of times before the places most liable to internal corrosion had been removed, and probably, if the head-gear were high, a number of such places existed in the length of rope between the pulley-wheel and the cage. Care should be taken that such places should be removed by cutting off sufficient rope when re-capping. The questions raised by Mr. Lees should be very carefully discussed by the members. There were a great many lives daily depending upon winding-ropes, and the failures in ropes necessitated a consideration of the reasons. He had investigated a great many cases of broken winding-ropes, but he did not remember ever finding one that had broken by being worn out. No engine-wright would certify that a rope was in good order if there were a large number of broken wires or appreciable wearing.

Breakages were generally due to internal corrosion, which could not be seen nor detected, and the question was suggested as to how long the rope should remain in use. Some managers made a rule to renew at the end of 2 or $2\frac{1}{2}$ years. They said—"Take it off then whether it is safe or not." He might express one opinion upon this: a rope that was working daily, drawing thousands of tons of coal per month, did not owe them much at the end of 2 years. He thought that a time-limit was a very important suggestion and should receive the attention of the members.

Mr. L. T. O'Shea (Sheffield) said that Mr. Stokes had asked an important question as to galvanized wire rope and its property of resisting the corroding action of water. Mr. Stokes said that it was possible that the galvanized coating might crack under the varying strains to which the rope was put. If it did so, the corrosion which took place in galvanized wire, where the iron was exposed by the galvanizing material cracking off, would be greater and more rapid than in un-

galvanized wire, owing to the fact that electric action was set up between the two metals. If galvanized wire was used for constructing winding-ropes, the rapid corrosion which would take place under the above conditions would form a great source of danger.

Mr. H. B. NASH (Barnsley) remarked that Mr. Stokes, in his investigations of a number of cases of broken winding-ropes, stated that the greater number of breakages had occurred near the capping and the pulley-wheel, which were the most dangerous parts and the weakest parts of the rope after re-capping. One naturally expected that the part of the rope nearer the drum and nearest the capping would prove the weakest—as the greatest strain was put upon these parts when starting winding. He (Mr. Nash) could not follow Mr. Stokes' line of reasoning, as to that particular part of the rope giving way owing to an insufficient length of rope having been cut off when re-capping. His experience had not led him to that conclusion, but, of course, it had not extended over so long a period, nor in such a variety of cases as Mr. Stokes'.

Mr. STOKES said that, in his experience, by far the largest number of broken winding-ropes had broken between the cap and the drum, and were frequently within a short distance of the cap. One other point that he had omitted to mention might illustrate his opinion. Taking a rope that went over the pulley and under the drum, it stood night after night probably with the cage at the top or at the bottom of the shaft, and water would be trickling down the rope in small quantities, until at the point where it touched the circle of the drum, a considerable amount of moisture would be accumulated—to the detriment of the rope. In cutting off the cap, one of these places might pass on to the top of the pulley, and this constituted a second danger.

Further discussion was adjourned.

Mr. L. T. O'SHEA read the following "Report on an Explosives Testing-station":—

REPORT ON AN EXPLOSIVES TESTING-STATION.

The Joint Committee appointed by the Chesterfield and Midland Counties Institution of Engineers and the Midland Institute of Mining, Civil, and Mechanical Engineers have considered the form of station suitable for testing mining explosives, and while taking the gallery at the Consolidation colliery,* near Schalke, in Westphalia, as a pattern, it recommends the erection of one in which many modifications have been introduced, so that the conditions under which explosives can be tested may be extended beyond what has hitherto been possible.

The considerations which have influenced the Joint Committee in recommending the station described below are as follows:—In the first place, it considers that it would be useless to recommend the institutions to erect a station in which experiments can only be conducted on the same lines as those followed in existing stations; and, in the second place, it considers it is most desirable that the experiments should be conducted on a scale which will command the confidence of mining engineers.

The stations at present existing can only be used for testing explosives in still atmospheres and in absence of props. The form now recommended will allow the experiments to be extended so as to test the effect of the ventilating current and of the presence of props, and so more closely approximate the conditions of shot-firing in a mine.

In this proposed station it will be possible to test explosives under the following conditions:—(1) In gaseous atmospheres; (2) in still dusty atmospheres with or without gas; (3) in dusty atmospheres without gas in a ventilating current, concurrent with or opposed to the direction of the shot-firing; and (4) in presence or absence of props.

The scale on which experiments can be carried out depends on the size of the gallery and the dimensions of the cannon. The diameter of the proposed gallery is fixed at 8 feet, with a cross section of 50¼ square feet, whilst the cannon will allow charges of 18 to 20 ounces to be fired. It will therefore be possible to fire shots of a similar weight to those used in actual work, which, in the Joint Committee's opinion, is most essential in such experiments.

The following is a general description of the proposed station, consisting of an explosion-gallery, a machine-house, and an observation-house:—

* *Trans. Fed. Inst.*, vol. ix., page 250, and Plate XVI.

The Gallery.—The gallery *G* consists of a circular tube 8 feet in diameter and 120 feet long, open at one end and closed at the other with a solid block of masonry *Ma* 12 feet high, 12 feet wide and 10 feet long, in which two cannons *C*, *C* are bedded (Figs. 1, 2, 3, and 4, Plate XXI.). The gallery is provided with 16 sight-holes *S* for observation of flames, those near the closed end being 3 feet and the others 6 feet apart.

Along the top of the gallery are seven safety-valves *V* for relieving the pressure of an explosion. An explosion-chamber *Ex* for holding gaseous atmospheres is made by fixing a paper diaphragm *PD* at a distance of 16 feet from the closed end, giving a capacity of 800 cubic feet.

On the sides of the gallery are bolted seven sets of special angle-irons *P* (Figs. 5, 6, 7, and 8, Plate XXII.), to which props and crossbars can be bolted. The distance between the sets of timber is 3 feet, four sets are placed in the explosion-chamber, and three sets in the gallery beyond.

For the purpose of drying the explosion-chamber or raising the temperature of the atmosphere, a steam-pipe *SP* runs along both sides of the chamber and across the end nearest the diaphragm.

The explosion-chamber is connected with a fan by means of iron pipes *CP* (6 inches in diameter), for the purpose of circulating the gas and air and obtaining uniform mixtures. One pipe joins the gallery at the top near to the closed end, and the other at the bottom near to the diaphragm, both pipes being fitted with taps. The gas enters by a pipe *GP*, and the displaced air escapes by the pipe *EP* (Fig. 6, Plate XXII.).

Two cannons *C*, *C* are provided, one arranged so that the line of fire can be observed from the sight-holes. The other is placed at the bottom of the masonry-block. The cannons consist of cylinders of forged mild steel, 4 feet long and 2 feet 2 inches in diameter, having holes 3 feet long and 2 inches in diameter drilled along their axes. The cannons are inclined so that their axes produced meet at a point 60 feet from the closed end. They are backed with sheet india-rubber 1 inch thick, and 2 inches of willow wood.

To produce the ventilating current, two holes *BP* 2 feet in diameter run through the masonry-block. These can be closed on the inside of the gallery by hinged doors, which can be firmly fastened against indiarubber packing, by means of chains and screws which pass through doors at the other end of the tubes, and can be fastened with nuts. By this arrangement the doors can be opened and closed without entering the gallery, and a perfectly air-tight joint made. These tubes are connected with the fan by means of a box or trough *T*, which is lightly covered with wooden lids to break the force of any explosion that may travel in the direction

of the fan. The gallery is sunk in the ground for a depth of 4 feet, and the side opposite to the sight-holes is banked up with soil for a further 3 feet.

Machine-house.—The machine-house is placed at a distance of 30 feet from the gallery, but in Fig. 5 (Plate XXII.) is shown as adjoining, so as to economize space. It consists of a wooden shed, 14 feet long by 12 feet wide, with a slate roof. It contains a Schiele or Capell fan *F*, 40 inches in diameter, and capable of passing 17,000 to 20,000 cubic feet of air per minute at 1,000 revolutions. This fan is driven by a horizontal engine *E*, with a cylinder 11¼ inches in diameter and 20 inches stroke from a counter-shaft *CS*. The fan is connected with the box or trough *T*, and a series of valves are arranged so that it may be used as a blowing or exhausting-fan. Valves are also introduced to allow the box or trough to be cut off, so that the fan can be used to circulate the air and gas in the explosion-chamber.

The gas is delivered from a telescopic gasometer *M*, 4 feet in diameter and 5 feet high, with a capacity of 96 cubic feet or 12 per cent. of the capacity of the explosion-chamber. The gas enters the gasometer through a gas-meter.

Observation-house.—This house is situated at a distance of 30 feet from the gallery. It consists of a wooden shed, 16 feet long by 12 feet wide, with a slate roof. It is divided longitudinally by a partition, 4 feet from the side facing the gallery, so that a dark-room is formed from which observations can be made through a slit running the length of the building and placed at such a height from the floor that the line of sight intersects the line of fire of the upper cannon (Fig. 4, Plate XXI.). The other division of the observation-house is fitted with bench, cupboards, shelves, etc., and forms a laboratory for making tests of the gaseous mixtures, etc., on the spot, when necessary.

A small shed, 6 feet long and 4 feet wide, adjoining the observation-house, is fitted with table and pigeon-holes. It should be licensed as a store for explosives, and is intended as a house for keeping the daily supply of explosives when experiments are being carried on, and as a house for weighing up the charges. It is not proposed to use this as a magazine, as it is hoped that permission will be granted to use the magazine of the colliery in the neighbourhood of which the station is erected. If this be not possible, a magazine would have to be built.

Cost of Station.—Two estimates have been made of the cost of erecting the station, one for a steel gallery and the other for a wooden gallery.

The Joint Committee think that a wooden gallery offers greater adv
than a steel one :—Firstly, because it is cheaper ; and secondly, b
modifications and alterations can be made so much more easily.
wooden gallery is built on circular angle-iron hoops, covered wit
layers of pitch-pine boards 1 inch thick.

The cost of erecting a station having a steel gallery is £1,340,
sive of steam-pipes, gas-pipes, and water-pipes, and inclusive of lab

The cost of erecting a station having a wooden gallery is £
exclusive of steam-pipes, gas-pipes, and water-pipes, and inclus
labour.

It is impossible to estimate the cost of pipes for conveying
gas, and water to the gallery, as the length of piping will depend o
site chosen.

The above estimates are made for new machinery and materia
consequently the cost may be reduced by purchasing second-
machinery ; but, as the price of this varies, it was thought bett
estimate for new machinery, especially as it gives some idea o
approximate maximum cost. The cost would be further reduced
machinery was lent or presented by those interested in the testin
explosives.

The area required for such a station is about 210 feet by 75 feet, a
should be fenced in to prevent trespassing. The cost of fencing
included in the estimate.

In addition to the cost of erecting the station, funds would be necessary for carrying out experiments, including cost of explosives, gas, water, and steam, and the wages of two or three workmen to assist the engineers appointed to carry out the experiments.

Mr. L. T. O'Shea read the following "Memorandum on the Proposed Station for Testing Explosives at Woolwich" :—

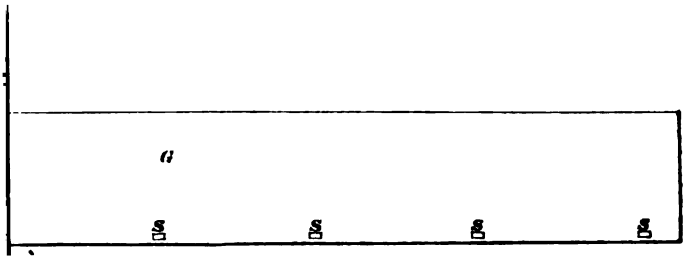


Fig. 3.

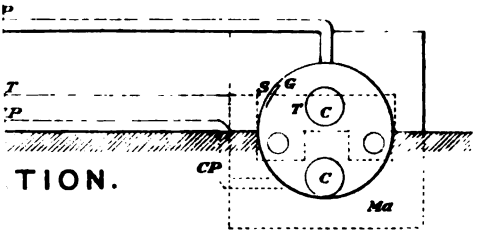
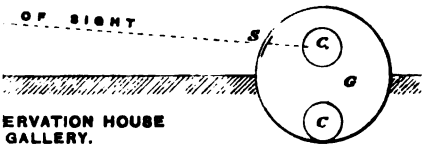
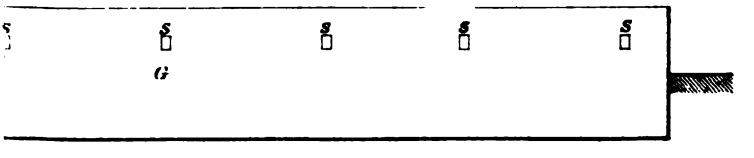


Fig. 4.





Scale, 12 Feet to 1 Inch.

on

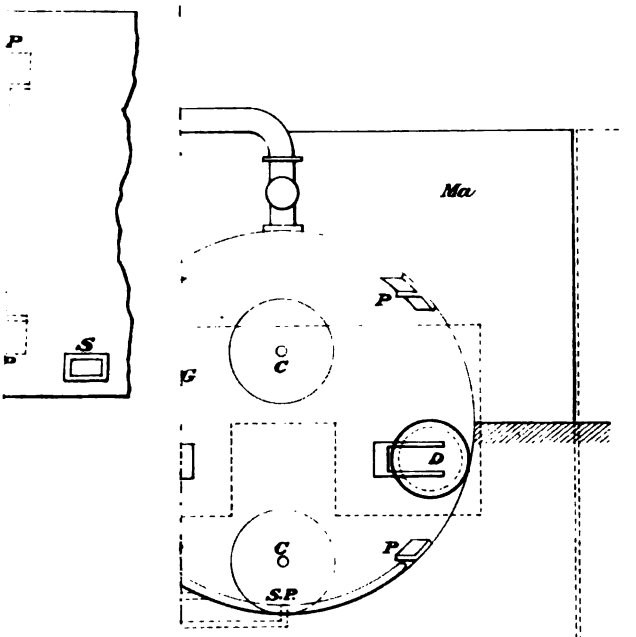


Fig. 6

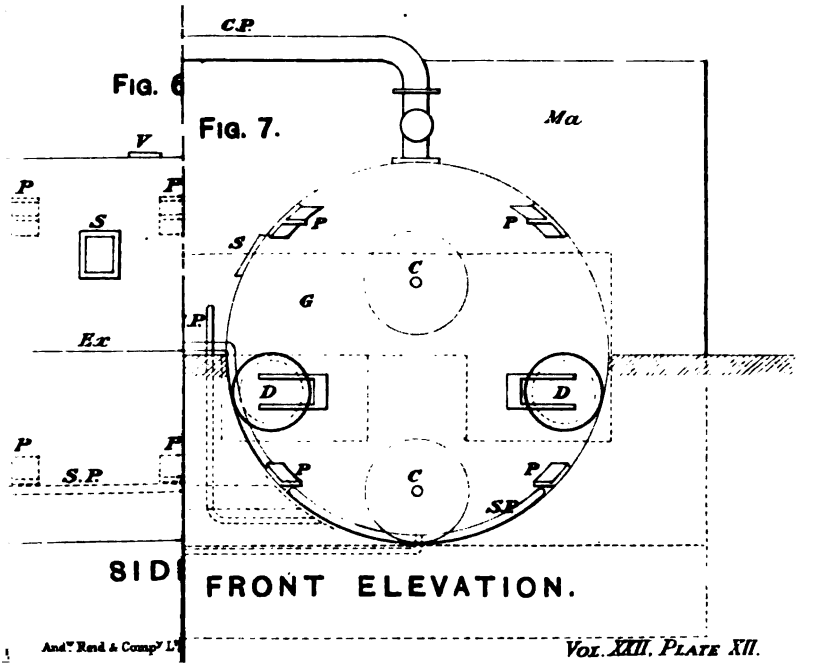


Fig. 7.

SIDE FRONT ELEVATION.

MEMORANDUM ON THE PROPOSED STATION FOR TESTING EXPLOSIVES AT WOOLWICH.

The Joint Committee of the Chesterfield and Midland Counties Institution of Engineers and the Midland Institute of Mining, Civil, and Mechanical Engineers, having considered what form of gallery is desirable for the testing of explosives for mining purposes, and having had before them the plans of the proposed gallery at Woolwich,* desire to call the attention of the Council to the following points, based on a comparison between the new gallery at Woolwich and that at the Consolidation colliery, Schalke, Prussia.†

The Committee is of opinion that any station erected for testing mining explosives should fulfil the following conditions in order that the results may have practical value:—

(1) It should be possible to fire charges as large as 18 or 20 ounces of any explosive, if necessary.

(2) The area of the cross section of the gallery should bear some reasonable proportion to that of the roadway in a mine, and in no case be less than 25¼ square feet, which is equivalent to a circular tube 6 feet in diameter.

(3) It should be so constructed that it may be possible to carry out experiments to investigate the following points:—

(*a*) The effect of the ventilating current.

(*b*) The effect of reducing the areas by the introduction of props.

(*c*) The influence of wet spaces in stopping explosions of dust.

(1) It is desirable to be able to fire charges up to 18 or 20 ounces. The experiments of Herr Bergassessor Winkhaus† show that there is a certain maximum weight of any explosive that can, under given conditions, be fired with safety. This is also the experience of two members of the Committee, who have had the opportunity of testing certain safety-explosives. Consequently, the dimensions of the cannon should be such that, if necessary, the weight of the charge can be increased to determine whether ignition of dust or gas can be effected by charges that are commonly used in actual working. How far this is possible with the cannon proposed for the Woolwich station it is impossible to say, as no details of its dimensions are given. In drawing the Council's attention to this point, the Committee would refer to the remarks of Mr. Hall, H.M. inspector of mines, on the Report of the Explosives Committee of

* *Trans. Fed. Inst.*, vol. xiii., page 612.

† *Ibid.*, vol. xii., page 32; and *Glückauf*, 1896. vol. xxxii., page 425.

the North of England Institute of Mining and Mechanical Engineers:—* "In these experiments, very small charges of explosives were used; possibly if larger charges had been used—charges such as would be used underground in firing shots—some of the results might have been different, for he believed it was admitted that even flame of a fixed temperature, if applied in large volume, would sometimes ignite a gaseous mixture which a small volume would not ignite. He thought it most desirable that, in future, experiments on this point should be taken into consideration, and that, instead of dealing with an ounce of the explosive, they should deal with the usual charges used underground."

(2) The area of the cross section of the gallery should bear some reasonable proportion to that of the roadway of a mine. Although it may not be practicable to erect a gallery whose cross section is equal to that of a main roadway, yet the Committee are of opinion that its area should not be less than that of a circular tube 6 feet in diameter. This opinion is based on that expressed by Mr. Winkhaus to two members of the Committee, who, in 1896, visited the Schalke station, with the express object of obtaining information on the most desirable form of gallery. They specially questioned him on the subject of the dimensions of a gallery, and he stated that his experience led him to the conclusion that there is some connexion between the area of cross section of the gallery and the relative safety of an explosive. In the gallery at Schalke, which is oval in shape and measures through its centre 6 feet by $4\frac{1}{2}$ feet, it is possible to obtain ignition with smaller weights of charges than in the similar gallery at Saarbruck, which measures through its centre $5\frac{1}{2}$ by $3\frac{3}{4}$ feet. In the face of such an opinion, the Committee feel that experiments carried out in a gallery only $2\frac{1}{2}$ feet in diameter can only lead to inconclusive results.

(3) It should be possible to extend the experiments. The effects of the ventilating current and of reducing the area of the gallery by the erection of props have not yet been tested, so far as the Committee is aware; and it is of opinion that if provision were made to enable these points to be investigated, not only would valuable information be forthcoming, but a further step would be taken towards approaching the conditions of actual working. The Committee is aware how far the conditions of experiment fall short of those of actual working, but feels that every effort should be made to approach the latter as closely as possible, and it regrets that no means should have been proposed for

* *Trans. Fed. Inst.*, vol. viii., page 229.

realizing these conditions. Another question for investigation is the effect of wet spaces in stopping dust explosions, and the Committee feel that a gallery 25 feet long cannot be used to obtain information on this important question.

In two other respects the Committee is of opinion that the gallery is capable of improvement.

(1) In the means proposed for testing explosives in dusty atmospheres. The firing of shots from a vertical cannon into a dusty atmosphere does not realize the conditions of shot-firing in mines. The conditions of experiment are much more severe, for dust is sure to fall into the shot-hole and increase the danger of ignition—such severity is unnecessary and hardly fair to the manufacturer.

(2) The position of the gasometer with respect to the fan and the gas-pipe leading to the gallery is such that, so far as can be gathered from the drawing, the gas and air during the process of mixing have to pass through the gasometer, and virtually the gasometer becomes part of the gallery. This appears to the Committee to be a disadvantage, as the capacity of the gasholder has to be taken into account in making a definite mixture of gas and air, and also because after the mixture has been made an explosive atmosphere must exist in the gasometer. Although this does not affect the conditions of the experiment, still it could have been avoided by placing the gasometer beyond the pipe leading into the gallery.

In submitting these criticisms to the Council for their consideration, the Committee begs to state that, having had under its consideration for some time the question of testing safety-explosives, it is firmly convinced that the proposed gallery fails in many respects to meet the conditions most favourable for obtaining conclusive results from a practical point of view; and as it is probable that the results obtained at Woolwich will be taken as standards for regulating the use of explosives in mines, the Joint Committee regrets that the conditions of actual working are not more nearly approached.

The CHAIRMAN (Mr. G. B. Walker) said that the recent Order in Council, limiting the number of explosives which might be used in coal-mines, had brought that question very much to the front, but they were not primarily concerned (as mining institutes) with the question which the Home Secretary had to settle, namely, what explosives should or should not be permitted in fiery mines. The supplementing of such

tests as would enable the Home Secretary to decide what explosives he would allow to be used was not primarily the object with which the two institutes started the idea of an explosives gallery; indeed, their action was antecedent to that of the Home Secretary. They wished to conduct such experiments in such an experimental station as would enable the members to set their minds at rest with regard to the dangers which would always attend the use of explosives in coal-mines, in order that they might arrive at the greatest amount of knowledge possible as to the conditions under which explosives might most safely be used. The institutes had no funds for such a purpose, and he suggested that a small contribution, spread over the members of the two institutes or the collieries represented by them, would be a trifle that none of them would grudge, and would be well repaid by the anticipated results.

Mr. M. H. MILLS, as a member of the Joint Committee, said that he was bound to acknowledge the valuable services that had been rendered by Mr. O'Shea and Mr. Blake Walker, who were mainly responsible for the report that had been presented that day. He must say that he had some little diffidence in discussing the new testing-station which was being erected at Woolwich, because he had very little doubt that the Home Secretary would hardly have entered upon such an important matter without obtaining advice from H.M. inspectors of mines. It was intended, if this testing-station were erected, that any agent for an explosives company whose explosives were being tried, or any coal owner who sent his dust to be tested, would be allowed to be present at the tests and be advised as to the results. He suggested that the County Councils and coal-owners ought to meet a very considerable portion of the expense, as it was for the advantage of the district that proper tests of explosives should be made.

Mr. A. H. STOKES (H.M. Inspector of Mines) remarked that H.M. inspectors of mines had not been collectively consulted as to the apparatus to be used in the testing of explosives at Woolwich; and he was not aware that any coal-mines inspector other than Mr. H. Hall had been consulted, either as to the apparatus or as to the tests required. He (Mr. Stokes) agreed with the committee's suggestion that the experiments should be carried out upon a scale equal to the actual conditions found in a mine, and he was strongly supported by Mr. Hall's opinion quoted in the committee's report; and also by Mr. Winkhaus, who made the Saarbruck experiments. The Chesterfield and Midland Counties Institution of Engineers—some years ago—made experiments in currents of

ventilation, both as to gas and air, and dust and gas, and under greatly varied conditions. The results had been published in a bulky volume,* which many of the members no doubt had seen, and these experiments proved the value of the remarks in the memorandum issued by the Joint Committee. The experiments were made upon a comparatively small scale, and the conclusions formed upon some of those experiments had subsequently been shown to be erroneous when similar experiments had been made upon a larger scale. If the Chesterfield experiments were compared with experiments made upon a larger scale, both at home and abroad, it would be seen how far the larger-scale experiments had negatived or modified the conclusions formed by the committee of the Chesterfield and Midland Counties Institution of Engineers and based upon small-scale experiments.

Mr. H. Bonser (Leeds) observed that the first testing-apparatus for explosives was erected by Mr. C. E. Rhodes at Aldwarke Main collieries, and in that apparatus tests were made in ventilating-currents charged with dust and 10 per cent. of gas, which were revolved rapidly in the apparatus at the moment at which the shot was fired. Mr. Rhodes tested all the then known explosives, and from the results of those tests decided to continue the use of gelignite in the water-cartridge. The next testing apparatus, he believed, was erected at Gathurst factory, near Wigan, by the Roburite Explosive Company. Another apparatus was erected by Mr. W. Foggin at North Biddick colliery, near Newcastle-upon-Tyne, and experiments were carried out there by Mr. W. Foggin and Mr. M. Walton Brown. Other plants were erected at the Ince Coal and Cannel Company's works, near Wigan, by the Westfalite Company; at Cymmer colliery, near Pontypridd, South Wales; at Abercarn colliery, South Wales; by the Wigan Coal and Iron Company, near Wigan; and at Hebburn colliery, near Newcastle-upon-Tyne, by the North of England Institute of Mining and Mechanical Engineers. He recognized the difficulty of going to Woolwich to make tests, as the dust would not be in the same condition as found in coal-mines, but might be nearly approached by being dried. The weight of an explosive used in the tests at Woolwich was the equivalent of 2 ounces of No. 1 dynamite, fired in a leaden block. In his own tests, he used a large cube of puddled clay and put into a hole a charge equal to 1 lb. of gunpowder, and he measured the displacement by pouring water into and ascertaining the size of the cavity by measuring the volume of the water; more

* *Trans.*, vol. x.

reliable results were obtained by this method than by using leaden blocks. In his opinion, the Woolwich testing-station was equal to any yet erected, but all of them were more or less defective. It was perfectly unnecessary to have a testing-station in this district, as no results of any test would be accepted by the Home Secretary.

Mr. A. H. STOKES stated that the Coal-dust Committee of the Chesterfield and Midland Counties Institution of Engineers were appointed early in 1879, and their experiments commenced in 1880.* He thought that Mr. Rhodes' plant was erected some time afterwards.

Mr. C. E. RHODES wrote that he commenced testing explosives in an explosive mixture of gas and air, travelling at varying velocities, and also in conjunction with coal-dust, in the year 1888, and erected an apparatus for that purpose at Aldwarke Main colliery. He was ably assisted by Mr. A. T. Cocking, who was then his assistant, and is now general manager of Messrs. Kynoch's works, at Birmingham and Arklow. He did not claim to be in any way the pioneer of testing explosives, and simply erected the apparatus for his own information.

Mr. C. J. MURTON (Barrow Collieries) considered, after four or five years' experience of the apparatus at Hebburn colliery, that the construction of the Woolwich apparatus, which ought to suffice for many years to come, constituted rather a retrogade step. Advantage had not been taken of the experience gained in this country and abroad. The present proposal of the committee for an experimental apparatus on a much larger scale was certainly more in accordance with what one considered to be the right thing for further experiments. He thought that the cost of the apparatus might be borne by the owners of collieries, and some of the associations looking after the welfare of the workmen might be asked to help. He suggested that representatives of these associations should act with representatives of the owners and other scientific gentlemen, and partake in the experiments intended to ensure mutual safety. The miners' representatives might throw out many useful and practical suggestions, and their participation would be beneficial to all. When dealing with the cost of a station they should allow something for the cost of attendants and repairs during the carrying out of the experiments. The expense, in the carrying out of experiments, in the way of attendants—engineman and labour keeping the station in order—would be considerable. The observers would have to number ten or more a day, so as to make the experiments of value.

* *Trans. Chesterfield and Derbyshire Inst. of Engineers*, vol. x.

Mr. H. R. Hewitt (H.M. Inspector of Mines) could not understand why the committee recommended that two cannons should be used in the proposed station, and why they should be "inclined so that their axes produced meet at a point 60 feet from the closed end." He believed it was suggested that these cannons should be fired simultaneously, and he begged to submit that shots like these were never simultaneously fired in a coal-mine. Although a steel gallery was the more expensive, he preferred it to a wooden one. It would offer more resistance and would make the sides of the gallery more resemble the sides of an underground road. If experiments in this direction were to be of any service they must be carried on under the same conditions as those existing in a mine, as nearly as it was possible to make them so. Seeing that the Home Secretary had taken this matter in hand he strongly objected to the money of the Chesterfield and Midland Counties Institution of Engineers being spent on the suggested station in this district. He understood that the testing-station at Woolwich was experimental only, and it was rather the duty of the members to show the Home Secretary that the gallery was unsatisfactory than to compete with him. The Home Secretary had undertaken the responsibility of naming safe explosives, and he for one would rather that the responsibility remained there. He certainly agreed with the committee that the present station was inadequate, and that misleading results would be obtained; and he believed that the station at Woolwich would shortly be greatly enlarged and improved. He suggested to persons making experiments that the pressures reached at various distances from the shot-hole should be registered, as was recently done at Liége by Mr. Jules Polain, who experimented with breech-loading guns. Mr. Polain found that the pressure increases and attains a maximum at $5\frac{1}{2}$ inches from the gun-face. After that distance was reached falling pressures were recorded. He also found that British gunpowder produced a dangerous pressure at a part of the barrel quite incapable of sustaining it, and further indicated that Belgian gunpowders did not show any such effect.

Mr. A. H. Stokes presumed that the Home Office station at Woolwich would be exclusively reserved for official use; and it was now suggested that another station should be erected by persons interested in coal-mines, where experiments could be conducted independently of the Woolwich station. In fact, there would be two rival stations which might do good by checking each other, and fighting out the claims of various makers of so-called flameless explosives. When he said that

there might be a separate station from that at Woolwich he meant a separate station anywhere in Great Britain, provided that it was commanded and governed by mining engineers generally, fixed in a suitable position for obtaining all the necessary conditions found in a coal-mine, and easy of access to mining engineers who wished to see the experiments.

The CHAIRMAN (Mr. G. B. Walker) said that the idea of the committee was that the members should erect their own gallery and conduct their own experiments, entirely independent of the apparatus at Woolwich. He was rather sorry to notice, from several remarks made in the room, that an impression had got abroad that they wished to compete with the official station. The experiments would be conducted on different lines and with different objects in view, yielding results which could not be attained by the Woolwich apparatus. Under these circumstances, they wished to have their own gallery, and he did not think that the cost ought to be prohibitive; coal-owners and others could find the money very easily, if they saw the advantages of having an independent testing-station.

Mr. H. B. NASH, seeing that the Home Secretary intended to test the value of explosives brought forward by inventors, thought it would be very absurd for the members, in case the Home Secretary said that a certain explosive was safe, for colliery-owners and managers to knock their heads against that statement by saying it was dangerous. He was opposed to the expenditure of any money upon the proposed station. The Home Secretary had taken the matter up, and the tests which he made should be final. If anything happened, they (as users of a permitted explosive) could say that it had been tested under conditions which justified the Home Secretary in considering it safe, and therefore they were entitled to rely upon it.

Mr. M. H. MILLS moved "that after consideration of the Joint Committee's report (presented to the Council of The Federated Institution of Mining Engineers at a meeting in London in June last), this meeting is firmly convinced that the proposed gallery fails in many respects to meet the conditions necessary for obtaining conclusive results from a practical point of view, and as it is probable that the results obtained at Woolwich will be taken as standards for regulating the use of explosives in mines, it regrets that the conditions of actual working are not more nearly approached."

The resolution was adopted unanimously.

DISCUSSION ON MESSRS. WALKER AND O'SHEA'S PAPER ON "RECENT PROGRESS IN THE RECOVERY OF BYE-PRODUCTS FROM COKE-OVENS."*

Mr. E. W. THIRKELL said that this paper dealt with the retort-oven as against the old-fashioned (so-called) beehive-oven; and one would almost think that the authors held a brief for the retort system, because they presented before them various ovens under that system of which, as against the old-fashioned oven, the members were led to infer that they were entirely in favour. Personally, he had had no experience with the retort-oven, but from a careful perusal of the paper he was led to believe that there was a great deal more in the system than many of them had thought up to the present time. By the retort system, the members were told that they could coke coal that could not be coked in the beehive-oven. That opened up a very wide field, because it implied that several coal-seams that could not be worked at a profit by selling the coal as the raw material, might possibly be worked at a profit if ovens could be adapted to make it into coke and extract the bye-products—the tar, the ammonia, what was got from the gases (benzol, etc.), in addition to the heating, and also what Mr. Bonser brought before their notice a few weeks ago, the recovery of cyanogen;† altogether there seemed to be (on paper) something like 3s. or 4s. a ton profit in all these subsidiary works, and if a careful study of the question in all its branches and bearings would bring that profit into a more practical form, it would be of very great moment. Retort-ovens were being built very largely on the Continent, and in Great Britain they were being adopted more and more. Mr. Walker had proved that his paper was practical by putting up some ovens himself under one of the retort systems. He would like to ask what the bye-product plant which Mr. Walker said would cost £25,000, would include. Then, of course, as was said at a previous meeting,‡ this coke might answer very well indeed for the ordinary purposes of blast-furnaces, but might not do at all for steel-melting and other purposes. The members ought not to be led away entirely by one system, but to look at the question from all sides. The paper also pointed out that there was a very large amount of waste in the present system of coking as compared with the retort system.§

* *Trans. Fed. Inst.*, vol. xiii., page 302. † *Ibid.*, vol. xiii., page 335.
‡ *Ibid.*, vol xiii., page 325. § *Ibid.*, vol. xiii., page 321.

The CHAIRMAN said that the gain was 10 to 15 per cent. of coke, and bye-products in addition.

Mr. THIRKELL (continuing) said that the tar was considered to be quite as good as gas-tar and particularly well adapted for coal-briquette making, an industry which might be taken into consideration at many collieries in these bad times, and if the bad times had caused attention to be directed to the recovery of what was now going to waste, then they had done some good. Coal at the present day was used very wastefully, but the time would come, in his opinion, when they would no more think of burning coal in the raw state than they would of eating raw meat.

Mr. M. H. HABERSHON (Thorncliffe) said that statements made as to the cost of plant were interesting, but another point of equal interest and importance, which had not been mentioned, was the cost of maintenance. If they looked at the drawings of the retort-ovens with flues in the sides and more or less complicated, the members would see that there must be considerable wear-and-tear of the fire-bricks. They knew what this amounted to with beehive coke-ovens, and some facts which would enable the members to compare the cost of maintenance of retort-ovens and beehive-ovens would add very much to the value of this paper.

Mr. M. H. MILLS remarked that at the present time he was wedded to the old-fashioned or beehive coke-oven, no matter how they might be constructed. When he managed a coking colliery in Durham there were beehive coke-ovens, and these made the best of coke. By the advice of a young engineer with new ideas, it was thought desirable to erect retort-ovens and recover the bye-products. A little money was made out of the bye-products, but not nearly so much as they lost by making an inferior coke, and they reverted to the beehive coke-oven. It was advisable, no doubt, to go abroad and see what was now being done, but it must be remembered that much depended upon the nature of the coal to be coked. They might make good coke with one class of coal, but the same oven might not suit another class of coal. After Mr. Blake Walker had had some experience of retort-ovens he would be able to give the members some practical results, which he hoped sincerely would be highly satisfactory.

The CHAIRMAN (Mr. G. B. Walker) observed that if every member waited until he knew all about a subject before he wrote a paper to be criticized by his fellow-members he was afraid that few papers would

be written. Abroad, rapid progress in coke-manufacture had been made during the past 10 years, and this did not seem to be grasped in our country. The failures of retort-ovens in Great Britain had created a prejudice against them, which still lingered despite the fact that scientific experts had been working at the subject ever since and evolving success out of failure. As far as he was able to judge, retort-ovens were now successful, not only in recovering bye-products, but in making excellent dense metallurgical coke suitable for blast-furnaces and foundries. Having made up his mind that this was so, he thought it was high time that the subject was brought under the consideration of the Institute, and he was convinced that whatever might be their misgivings that day they would, in the course of the next three or four years, learn much about coke-making, and have come to the conclusion that there was something to be said on both sides. There was no one in the world who was such an expert on the recovery of bye-products as Dr. Lunge, and he had produced a standard work on *Coal-tar and Ammonia*, which had held its place for the last 20 years, the last edition being 10 years old. That work contained very few errors or inaccuracies; what had been proved in connexion with gas-making, and what he had said with regard to coke-making, had been substantiated by ample experience in recent years in Germany, Belgium, and France. Dr. Lunge had written an article on "Modern Coke-ovens and their Bye-products" for *The Mineral Industry*.* He directed the attention of members to that paper, because Dr. Lunge's views upon that subject would have greater weight than the opinion of any other person in the world. It was astonishing how slow the progress which the idea of manufacturing coke under these conditions had made—not only in Great Britain, but in America. Dr. Lunge's paper was not published when he (Mr. Walker) wrote his, but he had carefully compared the statements made in the two papers, and he did not think that there was any substantial inaccuracy.

The cost of the plant was undoubtedly very large, but it depended upon the amount which they thought fit to expend. Still, £25,000 might be regarded as the smallest amount, because they could not put up a bye-product recovery-plant to deal with less than 1,000 tons of coal-slack per week. The cost of the condensing-plant was so considerable that 1,000 to 1,500 tons per week should be considered the minimum quantity of coal-slack that the bye-product plant ought to treat, and the least possible cost at present seemed to be £25,000. German coking-plants cost more, but they maintained that, by going in for high-class machinery, etc.,

* 1896, vol. v., page 179.

they recovered small percentages of valuable products which would otherwise be lost, and that what they saved by cleanliness and perfection was well worth the extra cost. At the same time the German coal-trade was a very much more profitable business than theirs in Great Britain. Of course, it should be borne in mind, when considering the cost of repairs of the beehive coke-oven and of the retort-oven, that in the one case they were constantly exposing the fire-brick to extreme changes of temperature, and in the other they were not. The object of the retort-oven was to keep the temperature of as uniform a character as possible. If the fire-bricks were of the right kind, and the walls of the floor not too thin, they might go on for some years without appreciably damaging the walls. German engineers had been trying to see how thin they could make the walls, and in the Semet-Solvay coke-oven these were very thin, but renewable. The main structure was independent of the flues, which were built of fire-brick lumps. It was not a serious cost to take out flues that had been burnt through and to renew them, but with regard to the other substantially-built flues it was not advisable to make them too thin. The experience of all engineers was now tending in the direction of thickening of the walls of the flues, and he was told that they should not be less than 5 or 6 inches thick. The only damage that took place to the walls of coke-ovens was in pushing out the coke. With bituminous coal, a certain adhesion to the walls of the oven took place, and parts of the fire-brick might stick to the coke, and so be pulled off. At Bearpark collieries, where retort-ovens had been used for 12 or 14 years, a great many of the ovens had not been repaired, and were in a fairly good condition internally considering their age, and he put this down to their not being subjected to such rapid changes of temperature as the beehive coke-ovens. He advised the members not to make the walls too thin, as by this means the life of the oven was diminished, and if they did sacrifice something in the rapid transmission of the heat they saved more in repairs.

Mr. THIRKELL asked what was the percentage of coke in the various systems.

The CHAIRMAN (Mr. G. B. Walker) replied that in some coals there was 75 per cent. of fixed carbon, whereas in others there was only 65 per cent. He could not, therefore, lay down any definite proportion, as it depended entirely upon the fixed carbon in the coal, and what was gained in coke was lost in bye-products. A class of coal producing 65 per cent. of coke in a beehive-oven would yield 77 to 80 per cent. of coke in a retort-oven.

Mr. H. B. NASH enquired whether it was not a fact that in Great Britain retort-ovens had not been able to manufacture good, reliable steel-making coke, and whether this had not resulted in keeping back the development of retort-ovens in this country. He was informed that the extraction of some of the bye-products affected the quality and hardness of the coke. He would like to know whether a satisfactory steel-making coke had been manufactured continuously in this class of oven in Great Britain.

Further discussion was adjourned.

DISCUSSION ON MR. GEORGE DUNSTON'S PAPER ON "THE EASTERN EXTENSION OF THE MIDLAND COAL-FIELD, AND THE EXPLORATION AT SOUTHCAR."*

Mr. GEORGE DUNSTON said, with regard to the question raised at the previous meeting by Mr. Blake Walker as to the conditions under which drainage operations were being at the present time carried on in that part of Lincolnshire on the western side of the river Trent, where the proposed colliery at Southcar would be situated, that the following table recorded the rainfall in the district during the last 16 years :—

	Inches.		Inches.
1881	21·37	1889	22·68
1882	30·34	1890	20·95
1883	29·02	1891	24·14
1884	15·09	1892	20·77
1885	21·13	1893	18·26
1886	25·14	1894	21·07
1887	15·23	1895	23·68
1888	22·46	1896	22·16

The water of the district was dealt with in three different methods. The river Idle, with its raised banks, carried all the water from Nottinghamshire through this part of Lincolnshire. The Hatfield Chase Corporation, who were responsible for about 8,000 acres, had no difficulty in dealing with the water by means of steam-driven centrifugal pumps, capable of pumping 350 tons of water per minute. The water was lifted into a drain, the banks of which had been raised for a distance of about 4 miles to the river Trent. The engineer was of opinion that the present

* *Trans. Fed. Inst.*, vol. xii., pages 515 and 522; and vol. xiii., page 330.

pumping-plant was capable of dealing with an additional 3,000 acres of water-area, if necessary. The cost of erecting the pumping-plant was equal to about 10s. per acre, and the maintenance, etc., cost less than 2s. per acre per annum. The Isle Common Drainage Commissioners, of whom he (Mr. Dunston) was reappointed chairman yesterday, had about 15,000 acres of land which was drained by gravitation, and the water issued by three outlets into the river Trent. He could assure the members that there was no such thing as that part of the country being flooded, and there was no fear of any flooding taking place. Assuming for the sake of argument that subsidence did take place by the working of the minerals, it would not be a costly operation to raise the 4 miles of banks a few feet. Opinions were divided as to whether subsidence would take place under the Secondary rocks. Quite near to Southcar, there was a large tract of land called Bullasacks, about 2 feet lower than the land at Southcar, and this year it was proved in the law-courts that this land was not liable to be flooded, and that it did not want raising: and although Parliament had passed an Act that this land along with other lands should be warped, still the Court held this land to be the most valuable of land, and granted an injunction against its being so warped or raised. If, on the other hand, it be assumed that the land did want raising by the river Trent, the cost of the warping operation amounted to £20 per acre. Where there were four valuable workable coal-seams, it would be a waste to the country to assume that, for the sake of an additional £20 per acre, these seams should not be worked and the country should not obtain the full value of the mineral. The question had been raised as to whether the two coal-seams could be worked together, and he should be very glad if some member would speak who had had experience of two similar seams being worked together. Another question which had cropped up, most probably out of Mr. Blake Walker's remarks, although they did not justify it, was that large quantities of water had been met with during the boring-operations. Mr. Nash could confirm his statement that no water was met with during the boring-operations, with the exception of a small brine-spring, which drained off at a depth of 1,820 feet. As would be seen on the section, an anhydrous gypsum seam, which was 8 feet 10 inches in one thickness, was there bored through. After this core was taken out of the borehole, it was polished in two parts, and looked very beautiful. Gypsum was valuable for settling or purification purposes, large quantities were used at Burton-upon-Trent, and if mills were erected, it could be used in the manufacture of plaster of Paris.

The CHAIRMAN (Mr. G. B. Walker) said that the members owed a debt of gratitude to Mr. Dunston for affording the information which he had presented to the institutes. By means of different borehole sections, the position of the Barnsley seam, and its probable continuance under Lincolnshire, had been set at rest. The only question which was not quite clear to his mind was whether Mr. Dunston intended to infer that, having reached the maximum depth at Southcar, the Coal-measures continued to rise eastward until they cropped out in the North Sea.

Mr. G. DUNSTON said that he did not think that at any point the coal-seams would be nearer the surface than at Southcar—not even at Saltfleet, on the Lincolnshire coast. He thought that the measures were flat as far as the Lincolnshire coast, and possibly the seams might crop up in the bottom of the North Sea, which was 70 to 80 feet deep round the outcrop. Prof. Green was of opinion that they would rise to the east in the sea, but run flat for some distance beyond the Lincolnshire coast. It was 45 miles from Saltfleet to the "Coal-pit" in the North Sea.

Mr. H. B. NASH said that he could confirm Mr. Dunston's statement with regard to the amount of water found in the boring. As the engineer who had charge of the borehole from beginning to end, the small amount of water met with surprised him. In the sandstone measures, he had expected to meet quantities of water which would be extremely difficult to deal with, but it so happened that at no point did the water rise more than 1 foot. Of course, the size of the borehole should be remembered, and if it had been a 16 feet pit there might have been more water. Mr. Dunston had referred to the working of seams in close proximity, like the portions of the Barnsley bed. He did not think for his part that it would be advisable to work the seams together, but they could both be worked satisfactorily from the same shaft after one of them had been worked 2 or 3 years in advance of the other, so as to give time for settlement. He was working seams, but not at such great depths, and he found on these lines that he could work them satisfactorily, but an excessive percentage of small coal was made in working the second bed.

The CHAIRMAN asked whether red sand had been found below the Magnesian Limestone.

Mr. NASH replied that sand was not found under the Magnesian Limestone. At that point the strata were dry, and water was forced down the hole to enable them to continue the boring.

Mr. M. H. HABERSHON enquired as to the means taken to ascertain the inclination of the measures.

Mr. NASH said that they bored with a diamond drill, and the measures appeared to be almost flat. The cores did not break at an angle, and the layers of the strata, of which the cores could be still seen to-day, were quite flat. There was no doubt that the inclination, if any, was very slight. He could not give any definite information as to whether the Coal-measures rise to the east or west. He did not think that it could be proved from a single borehole in what direction the strata really were rising. The core taken out might turn round in the borehole-box as it came up. From two boreholes a short distance apart, but not from one borehole alone, could sufficient evidence be obtained to prove conclusively whether there was an inclination to the north, south, east, or west.

The CHAIRMAN said that, if Mr. Dunston could obtain sections of other borings in the neighbourhood of Doncaster, the members would be indebted to him. The remarks that he had made with regard to the apprehended drainage-difficulty were especially valuable, coming from one who had to deal with the matter practically.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
HELD IN UNIVERSITY COLLEGE, NOTTINGHAM, DECEMBER 11TH, 1897.

MR. M. H. MILLS, PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen :—

MEMBERS—

Mr. JAMES BAGSHAW, Mechanical Engineer, Brampton Ironworks, Chesterfield.

Mr. JOHN BINGLEY, Colliery Manager, Bolsover Colliery, near Chesterfield.

Mr. ARTHUR BREALEY, Colliery Manager, Lings Colliery, Heath, Chesterfield.

Mr. HARRY ROSS SKINNER, Manager, Durban Roodepoort Gold-mining Company, Roodepoort, Witwatersrand.

Mr. FRANK TATHAM, Colliery Manager, Stanley, near Derby.

STUDENTS—

Mr. GEORGE CLARENCE ALLSEBROOK, Mining Student, Wollaton, Nottingham.

Mr. JOHN COCKS, Mining Student, Ansley Hall Colliery, Atherstone.

DISCUSSION ON "REPORT ON AN EXPLOSIVES TESTING-STATION"* AND "MEMORANDUM ON THE PROPOSED STATION FOR TESTING EXPLOSIVES AT WOOLWICH."†

The PRESIDENT remarked that at their joint meeting with the Midland Institute of Mining, Civil, and Mechanical Engineers in Sheffield, he enquired whether H.M. inspectors of mines had been asked to advise upon the station which had been erected at Woolwich. Mr. Stokes' answer at the time was that they had not, up to then, had anything whatever to do with that station. Since then, he believed, there had been some examination made by H.M. inspectors of mines, and he should like to ask Mr. Stokes whether he could say anything upon that question.

Mr. A. H. STOKES (H.M. inspector of mines) said that he should like to hear what the members had to say on blasting and the use of

* *Trans. Fed. Inst.*, vol. xiv., page 411. † *Ibid.*, vol. xiv., page 415.

explosives generally before he made any further remarks. He might, however, state that he believed all the inspectors of mines had recently seen the Woolwich explosives testing-station.

Mr. J. A. LONGDEN (Stanton) remarked that Mr. W. J. Orsman had recently stated that one of the permitted explosives recommended by the Home Secretary to be used in mines was found to contain 40 per cent. of sawdust and gave out a great flame. People might say:—Let there be plenty of explosives put in the list, and we can choose which we will use. The Home Secretary had appointed engineers who had tested explosives at Woolwich, and who stated that those put upon the list were suitable for use in mines. But if a colliery-manager used one of the permitted explosives, and unfortunately had an explosion, H.M. inspector of mines would probably say that it did not matter what explosives the Woolwich engineers recommended, the colliery-manager was responsible for any accident in his mine. The results of an explosion were most serious, even supposing it did not involve loss of life. One of the first things H.M. inspector of mines would say would be that they must cease using naked lights. That meant a considerable addition to the cost of getting coal. The question had been raised recently, and the workmen were asking twice as much for working with lamps as they did before, namely, 2d. per ton. The colliery-manager incurred personal risk by using an explosive which he was led to regard as satisfactory, and which he found in practice was not so. No explosive should be put in the permitted list for use if it were not perfectly satisfactory.

Mr. H. LEWIS (Annesley) said that the question of explosives was agitating the minds of colliery-managers. He believed that the Home Secretary would give them a list of explosives which were considered the least dangerous.

Mr. J. H. W. LAVERICK (Alfreton) said it seemed to him that the Home Secretary's intention was to allow a certain degree of latitude in the matter of explosives. He was glad to notice that the Home Secretary, at a recent meeting held in Yorkshire, expressed the opinion that gunpowder could be made as safe as any of the permitted explosives. If this should be so, they might yet see gunpowder on the list of permitted explosives.

Mr. GEO. LEWIS (Derby) believed that the members were all more or less of opinion that the use of explosives in mines should be abolished to the greatest extent possible. He wished that the members had before

them a little more information about the Woolwich tests. After the tests had been made, the members would have information which they could not otherwise have obtained, and in that way the tests would be very useful to them in the future. Of course, each of the manufacturers wished to prove—and rightly so, from his own point of view—that his was the only explosive in the market which could be safely used in mines, but, after all, responsibility came back to the colliery-manager, and there it would rest. He did not think that the Home Secretary, or anybody else, would take the responsibility of choosing which of those explosives might be used in any mine, but the list of explosives that passed the test very much simplified the matter, and it was for colliery-managers to choose the particular explosive which would be the least dangerous in the circumstances in which it had to be used. With regard to those members of the Institution who had worked up the question, he thought that they should be thanked for bringing the subject forward, and so assisting in developing ideas which might prove useful in the future. If any member could give information as to the actual results in using any of the permitted explosives it would be very serviceable.

Mr. A. H. Stokes remarked that the "list of permitted explosives" simply implied that the explosives on that list had passed satisfactorily through the tests at Woolwich. It gave no guarantee of absolute safety; and the question whether the Woolwich test was sufficient to satisfy managers as to the safety of an explosive, or whether it was in any way better than the tests made by other engineers, at home and abroad, was a subject which had been brought under discussion by the publication of the report. Mr. Henry Lewis had asked what particular explosive he should use in a fiery mine. It was very easy to reply to that: it rested with the owner or manager of the mine to select the most suitable from the "list of permitted explosives," and to fire it only under safe conditions. Mr. Laverick had suggested, by his remarks, that high-grade gunpowder might eventually come upon the list. If that were so, and gunpowder, with other explosives from A to Z, obtained places in the list, together with that wide paragraph which governed their use—the finding of gas "indicative of danger"—what happy people they would all be! In his (Mr. Stokes') opinion any gas was dangerous, because its extent was generally unknown, and a trace at one point might lead to an unknown larger quantity. He could not say what had been done at Woolwich, as he was only there one day. He approved of Mr. George Lewis' remark that

the "use of explosives in mines should be abolished to the greatest extent possible." He requested the members to turn their attention to the practical part of the question and not discuss what they were doing at Woolwich, or what the new "list of permitted explosives" was likely to be, or what Mr. Stokes thought about it, or would select. They should state what experience they themselves had had with high explosives during the last six months. Had any explosives failed or any been a success, and what were their difficulties? Managers must not think that any one explosive selected from the list would do everything which blasting-powder had been doing formerly. A high explosive which was a success in one coal-seam might be a failure in the next, and they could only tell which high explosives would be successful in coal by their own experience. He had watched the use of explosives, and had sometimes seen a single shot-hole in the middle of the ripping, and the result had been a sharp explosion cutting its way down and leaving a considerable quantity on each side to be trimmed away. If, instead of putting one shot in the middle, two smaller ones had been placed one on each side they would have brought the ripping down just as well as gunpowder, and saved the cost of after-dressing. All the explosives would act fairly well in gateway or ripping, and the same remark applied to stone-drifts.

The PRESIDENT remarked that he would like to explain the position of this Institution in the matter. Some time ago, Mr. G. Blake Walker examined a testing-station in Westphalia, and made careful notes about it, and afterwards a Joint Committee was formed to consider the advisability of erecting a similar station in that district. During the time this was being considered they found that a testing-station was being erected at Woolwich, but had then no knowledge as to what that testing-station would be. The Committee went into the consideration of the plans and notes that Mr. G. Blake Walker had made, and prepared a report, which was submitted to The Federated Institution of Mining Engineers, and afterwards ordered to be printed in the *Transactions*. During the London meeting in June, 1897, the members were allowed to examine the explosives testing-station at Woolwich. The members could not expect the Home Secretary to state that there were one, two, or three explosives which they might use with perfect safety. The station had been erected to show whether one should attempt to use the so-called safety-explosives, and whether there was anything dangerous about them. The Joint Committee said at the time that the Woolwich station, and the apparatus, was not adapted for the purpose; and their words had

been proved true. A certain explosive, they were told, was safe to use, and they were now informed that it was not safe. The Joint Committee of the two Institutes proposed that a station should be erected in that district. Some of the members did not think that it was necessary, but he thought that they must now have altered their opinions. A station was necessary to test the explosives under the conditions of practical mining. The members could not expect the Home Secretary to do that for them, and for that reason he felt that this station should be erected by the coal-mining community to do work which it could not possibly be expected that the Home Secretary would do for them. Mr. Stokes had said that he would like the members to give what experience they had had at their own pits. A pit was not the right place in which to try high explosives. Before being tried in the pit, explosives ought to be tried at a proper testing-station. Of course, many of the members had tried various explosives, and had found that there was very little difference between them, and some were cheaper than others. He had tried electronite, which seemed to be satisfactory.

Mr. J. T. Todd (Blackwell) said that in view of recent legislation, by which the use of blasting-powder was to be prohibited, he had for some time past been trying two or three safety-explosives. In the Alfreton deep soft coal-seam the quantity of explosives used was:—roburite, 46 oz.; carbonite, 48 oz.; and blasting-powder, 75¼ oz. The cost per ton on round coal was ½d. per ton more with high explosives than with ordinary powder; whilst the percentage of slack was 20·61, 18·48, and 16·88 respectively. The length of coal-face was 114 feet, holed to a depth of 5 feet in each case. The stall was carefully swept up before each test, and all the coal and slack produced were sent to the surface and then screened and weighed. Coal-owners had to face the fact that the coal was shattered by using safety-explosives, and although in many cases it might be necessary to use them where there was a probability of gas, yet there were many cases in which ordinary blasting-powder would not be dangerous. His experiments were made, so as to test as fairly as could be the comparative results obtained by using roburite, carbonite, and gunpowder; all charges were carefully apportioned, and both slack and coal were weighed.

Mr. T. Machin (Silver Hill Colliery) said that roburite had been used at the colliery under his charge for about 18 months, and in his experience it did not do the same work as blasting-powder. He agreed with Mr. Stokes, that a shot put into the middle of the ripping cut

through and left the sides; but to use two shots would, he thought, be expensive. Roburite and carbonite also had been tried, and each made considerably more slack than blasting-powder.

Mr. T. G. Lees (Clifton Colliery) stated that ammonite, carbonite, bellite, and westfalite had been tried at Clifton colliery, but not in a way which would enable them to register the percentage of slack, though they could see from the effect of the shot in each particular case that the percentage of slack would be larger. Instead of the coal being brought down in the same way as by blasting-powder, it was broken up into thin slabs. Experts were present at the trial of each explosive, and they recommended the use of about half the weight of each safety-explosive as compared with that used with blasting-powder. It was found in every case that, even with half the quantity, the safety-explosive shattered the coal more than with powder. In a stone-heading, a shot would sometimes simply blow a large hole out just where it was inserted, and the effects did not seem to spread in the same manner as with blasting-powder. Very little difference was found as to the action of the four explosives mentioned when used in gate-ripping, and each appeared to do the work equally as well as blasting-powder.

Mr. A. S. Douglas (Hucknall Torkard) said that he had tried electronite, carbonite, and roburite in a thin coal-seam. He was assisted by engineers representing the manufacturers of the different explosives, but, personally, he could barely see the slightest difference between them. All the explosives seemed to do the work equally well, although, of course, the conditions were not exactly the same in each experiment. He thought, with the President, that there ought to be some indication as to what explosive should be used, otherwise they might be experimenting with all on the list.

Mr. G. S. Bragge (Swadlincote) said that he had used high explosives for a good many years, and he agreed with the previous speakers. He did not care to use any of them in getting coal. It was only with the very greatest care indeed—attending to everything personally, regulating the charge himself, and so on—that he had ever been able to get the percentage of slack anywhere near to what the colliers obtained when using blasting-powder. He had tried three safety-explosives for ripping, and he did not see much difference in the results. He had made careful experiments as to the quantity of slack produced, which proved an increase of between 1 and 2 per cent. in the slack over that produced with gunpowder.

Mr. HENRY STEVENSON (Pinxton) said that he was not in a position to speak with any authority, but he had used roburite in the Black-shale coal-seam. When the stemming was being made only the last 2 inches were rammed, and they obtained as good a result as if blasting-powder had been used. The proportion of the charge was at the rate of 1 to 3. In ripping with roburite they had fair results right through.

Mr. ALFRED CHAMBERS (Eastwood) thought that safety-explosives gave better results than blasting-powder in ripping, but in his judgment they were unsuitable for getting coal.

Mr. J. H. W. LAVERICK considered that a great deal depended on the particular seam of coal. At Riddings colliery, high explosives had been used in different seams, and in the Low Main coal-seam, where gunpowder answered fairly well, safety-explosives certainly shattered the coal. In the Deep Hard coal-seam, there was an increase in the quantity of slack over that produced by blasting-powder, but not so great as in the case of the Low Main coal-seam. With regard to ripping, they found high explosives to answer fairly well. Of course, in shot-firing with high explosives, there was the inconvenience of having to carry a battery and cable. He might add that in the sinking of staple-pits from one coal-seam to another, and in stone-headings they had found that safety-explosives compared very favourably with blasting-powder.

Mr. C. H. OAKES (Alfreton) said that Mr. Stevenson had alluded to the stemming, and he thought there was a great deal in that. He found that if the stemming were fairly tight the result was disastrous, but if it were somewhat light, the result was much better. If anyone else had had experience with regard to the stemming, he should like to hear it.

Mr. J. A. LONGDEN said that the use of high explosives meant increased cost. Experiments had been made at some of the collieries with which he was connected, and the increase in slack had been ascertained to be 2 per cent., and this meant 1d. per ton on the total sales; and 1d. per ton on the total sales in the Midland district represented a loss of £80,000 a year. If the Woolwich experiments were to be of any value they should as a result provide the members with an explosive which was perfectly safe. He objected to experiments being made locally with explosives, and it seemed to him that the question was a national one, and the Home Secretary ought to take the whole of the responsibility, only putting in his list such explosives as were flameless. He hoped

that Mr. Stokes, who was their representative in mining matters with the Home Secretary, would bring this matter before him. There ought to be a Government testing-station, where colliery-managers would be allowed—free of charge—to satisfy themselves that the explosives which they proposed to use were safe.

Mr. A. H. STOKES traversed the remarks of previous speakers, observing that if the increased cost of 1d. per ton would save half the lives that were lost by gas and dust explosions it would be money well spent. He adhered to the opinion which he had expressed that, in the case of ripping, two small shots were better and less expensive than one large shot, because hand-labour in dressing up the ripping was saved. He agreed that there was a great deal in the stemming of a shot, and many explosives which were safe with a good length of stemming would be quite unsafe in a gaseous mixture, without stemming. He did not know of one explosive which, if fired openly in a gaseous mixture, would not fire the gas.

Mr. C. H. OAKES said that the consumers of house coal did not want their cellars filled with slack; and it was, he believed, a fact that coal got by safety-explosives was a great deal more injured during transit by rail. No matter how small the charges they used in a *neshy* coal like the Low Main coal-seam, the explosive simply split it up. Every form and method of regulating the stemming had been tried in the Low Main coal-seam, and successful results had never been obtained.

Mr. A. H. STOKES said that he did not recommend any regulation of the stemming. The stemming must be sufficient to hold the shot, and he would never use less than 6 inches to any shot.

Mr. H. R. HEWITT (H.M. Inspector of Mines) observed that the general opinion at the meeting at Sheffield seemed to be that no fault could be found with the Woolwich testing-station except that it was not large enough for the purpose required. After looking at the plans, he was of opinion that the plant was properly arranged for testing explosives, but the results would not be obtained under conditions similar to those which prevailed in coal-mines. He must protest against the money of this Institution being used for testing explosives. The Home Secretary had undertaken the responsibility, and he thought that it should remain there.

Mr. C. H. SEELY, M.P., said that he was not prepared to go through the plans; but in his opinion there should be no doubt whatever as to

the efficiency of the testing-station at Woolwich, and no pains spared to ensure that the explosives were properly tested, and tested under conditions similar to those which would apply in a colliery. When a number of lives were dependent, to a certain extent, on these explosives, there was no question that when the Home Secretary tested them he should test them fully, thoroughly, and satisfactorily. If there were the smallest doubt about that being the case, he was sure that the moment it was brought to the attention of the Home Secretary it would be altered, and anyone who had any doubt should put his case before the Home Secretary. He hoped that all doubts would be fully discussed.

The PRESIDENT thought the members were agreed that, if the Home Secretary undertook the work, they had a right to expect that it would be properly done, and they were not satisfied of that at the present time.

DISCUSSION UPON MR. E. F. MELLY'S PAPER ON THE "USE OF STEEL GIRDERS AND PROPS IN COAL-MINES."*

The PRESIDENT remarked that at a colliery in Yorkshire, with which he was connected, a few steel girders were used in main roads, and they undoubtedly had some advantages, one of which was that they did not take up quite so much room as timber.

Mr. J. T. TODD said that steel girders were in use at Blackwell colliery, and he believed that their use had been proved satisfactory and economical.

Mr. C. R. MORGAN (Tibshelf) said that steel girders were used at Holmwood colliery, and found satisfactory in main roads, especially in the Tupton coal-seam. Some time ago they did a long length of road that had stood well. They were not used at the face.

Mr. HENRY STEVENSON said that the writer of the paper omitted mention of a flat mild steel bar to be used at the coal-face. He was using a bar 4 inches wide by $\frac{5}{8}$ inch thick. Its cost was 2s. 2d. as against 5d. for wood, and it had paid for itself in 8 months. Not one had broken yet, though they had been in use for 18 months. When considerably bent they were easily straightened. The increased height obtained by their use in a low seam was an advantage.

* *Trans. Fed. Inst.*, vol. xiii., page 277; and vol. xiv., page 398.

Mr. JAMES MEIN (South Normanton) said that he had tried a practical experiment with the object of testing the comparative efficiency of wood and steel. A number of steel girders and some settings of 6 inches Norwegian timber, were placed alternately. In a week or ten days, the timber was broken, and, as far as any safety was concerned, it was useless. The bars had, in the meantime, become slightly fastened at the ends by side movement or crush, but were quite secure, and showed no sign whatever of breaking. The girders were sometimes slightly bent, and as soon as they bent 6 inches or so in a length of 7 feet, they were taken out and turned over, and were found to be stronger than when they were straight.

Mr. A. S. DOUGLAS said that he always looked on wooden props as danger-signals when they began to crack. He regarded steel props as having too much rigidity, and, therefore, would prefer to use timber at the face. It might be that, in the long run, steel was cheaper than timber, but he preferred the latter for several reasons: the danger-signal was one which he knew was often depended upon by colliers.

Mr. ALFRED CHAMBERS thought that steel might be used with great advantage in a low place, but there was danger if it was used at the face where the seam exceeded 4 feet or 5 feet in thickness. A flat bar, such as Mr. Stevenson had spoken of, was much cheaper than a wooden bar.

DISCUSSION UPON MR. JAMES MEIN'S PAPER ON "THE WALKER HOLLOW NEEDLE FOR FIRING HIGH EXPLOSIVES."*

Mr. JAMES MEIN stated that Mr. Walker had considered the dangers pointed out by Mr. A. H. Stokes and Mr. M. Deacon at the last meeting, and had so far modified and altered his arrangement that it was now, with its use, quite impossible for any of these accidents to occur. The ramming was done with safety, because during that process there was no detonator to fire the charge. The ramming being completed, the detonator was put in its place, and the battery connected. If the detonator was a bad one they detached the battery, removed the detonator, and put in a fresh one. They could repeat that removal any number of times, and if they should get several bad detonators in succession they would not have a missed shot, provided the final detonator was a good one. The cane springs, which it was suggested

* *Trans. Fed. Inst.*, vol. xiv., page 164.

might by friction fire the detonator, had been done away with. The hole left by the hollow needle in the stemming was only $\frac{3}{8}$ inch in its internal diameter, and if the shot-hole was 2 inches in diameter there was 16 times more area rammed than was left unrammed; it was therefore extremely unlikely that this small proportion of unrammed space would have any weakening effect on the stemming. Experiments proved that the shots in every case did the work required, and that the stemming was not in the least weakened by a hole being left by the needle. He did not agree with Mr. Hewitt's statement "that there was very little use for the Walker apparatus." Mr. Stokes, in his last year's report as H.M. inspector of mines in the Midland district, gave particulars of 6 accidents resulting in very serious injury to 8 persons, due entirely to missed shots or to hard ramming. He ventured to say that if the Walker method of firing high explosives had been in operation every one of these accidents would have been avoided. It had been suggested that these accidents were due to the carelessness of workmen in indulging in hard ramming, and this was wellknown to be a serious breach of rule. He suggested, however, that instead of making rules, which were easily broken, it would be better if they, as mining engineers, turned their minds towards the improvement of principles and methods by removing as far as possible, as in this arrangement, all danger.

Mr. J. T. Todd said that the Walker arrangement appeared to have two principal advantages:—(1) it was not necessary for an ordinary workman to insert the detonator—that could be done by a competent person; and (2) if the detonator missed fire it could be withdrawn, and another inserted without any risk. He found that there were about $7\frac{1}{2}$ missed shots to every 1,000 fired, and the question arose as to the economy of this arrangement. Mr. Walker stated that the cost was $\frac{1}{2}$d. per shot; 1,000 shots, therefore, represented 41s. 8d., and out of that number they had $7\frac{1}{2}$ missed shots. The question was—would it not be more economical to incur that expenditure than to redrill the holes, and put in new charges, or allow the places to be fenced off for a certain number of hours before they could be again approached? He (Mr. Todd) had a practical illustration in one or two shots that were fired a short time ago. The first was fired in the ripping and exploded; the second shot was at the coal-face, and was a miss-fire, whereupon the detonator was withdrawn without any trouble, and on a second detonator being inserted the shot was exploded. Possibly the withdrawal of the detonator might be regarded as partial unramming of a shot, and breach of a special rule. The detonators in both cases were low tension.

Mr. H. STEVENSON said that he had had the figures taken out at the colliery for the past three months, and he found that out of over 8,300 shots there had only been 2 miss-fires. The shots were all fired by high-tension electricity. The loss of those two shots represented 4s. 6d., while the Walker appliances would have cost £17 6s. 2d.

Mr. A. H. STOKES asked Mr. Todd whether the two fuzes had been tested by a galvanometer before being used?

Mr. TODD replied that he could not say whether they had, or had not, as he was not there when the shots were fired.

Mr. A. H. STOKES said that he had not known a single failure of a low-tension fuze, provided that it had been tested by a galvanometer and found good immediately before being used, and provided that it was properly placed in the hole.

Mr. CHAS. LATHAM (Nottingham) asked whether the detonator, which they had been told missed fire, had been tested. Many missed shots of which they heard were due to neglect in making a perfect coupling between the wires of the cable and those of the detonator. Then, again, it sometimes happened that batteries were allowed to run down, and if they were not kept up to their proper standard they could not do their work.

Mr. J. T. TODD replied that if the battery had run down it would not have fired the second shot.

Mr. A. H. STOKES remarked that it was now suggested by electricians that the firing of low-tension fuzes should not be effected by a primary battery, but by a magnetic battery, as they found that primary batteries ran down until they would not work.

Mr. G. E. SMITH (Nottingham) said it had occurred to him as a possible explanation that a smaller current would pass through a galvanometer than would be required to fire a shot, especially if the resistance of the fuze was high. It was quite possible, therefore, that fuzes which had been tested might miss fire through the cause that he had mentioned.

Mr. LONGDEN remarked that a short time ago, at Langwith colliery, a detonator missed fire, or was taken out of the hole, and another was put in and the shot fired with the Walker arrangement.

At the request of the PRESIDENT, who had to leave the meeting, Mr. J. A. LONGDEN then took the chair.

DISCUSSION UPON MR. T. G. LEES' PAPER ON THE "INTERNAL CORROSION OF WIRE ROPES."*

Mr. T. G. LEES, replying to the discussion at the Sheffield meeting, said that if managers only recapped the rope once in 6 months, and then only cut off 6 feet, they would be a long time in getting bad pieces out of the way, but if they cut off 12 feet they got rid of these bad pieces much more quickly. Mr. Stokes suggested cutting off more than 12 feet of rope, because the worst part of a rope was between the cap and the pulley; and that it would be better to cut more off, even to the back of the pulley; and he agreed that it was better to cut off too much rope than too little. His (Mr. Lees') experience with endless-rope haulage on heavy inclines had been that ropes were considerably stretched, and if non-adjustable clips were used, considerable difficulties would ensue. A rope with a solid core kept its shape; there was little trouble with the clips, and the stretching was much less than with a hempen core. The iron core formed a solid base for the outer wires to bed upon, and they did not find that it injured the strands of wire in any way. There was no difference between a hempen core and a wire core in passing round curves. Mr. Stokes seemed afraid of the galvanized coating cracking, and allowing the water to attack the wires. Prof. O'Shea stated that if the galvanized coating did crack in bending, galvanic action would be set up between the zinc and the steel, and speedily end in the destruction of the rope, but in practice it did not crack, and they would soon find it out, if that statement were true. The effect of galvanizing was to reduce very slightly the tensile strength of the wire and the reduction of strength in the torsion-test was rather more, but in either case it was very slight. The idea was not a new one, as galvanized wire had been used for winding ropes for something like 20 years or more at collieries troubled with bad water. He thought that there was danger in fixing a limit for the life of a rope, say at 2 years, and deciding that at the end of that time the rope must be taken off. He was afraid that such an idea would probably introduce the temptation of buying a cheap rope. The best winding-rope in the market should be bought, and run as long as experience proved it to be safe. His opinion was that a colliery-manager, who was responsible for the safety of his workmen, should buy the winding-rope, and should say how long the rope should run and when it should be taken off.

* *Trans. Fed. Inst.*, vol. xiv., page 400.

Mr. A. S. DOUGLAS said that he was quite in sympathy with the concluding remarks of the last speaker. There appeared to be an unwritten rule that 2 years was the life of a winding-rope; and when a rope had run 2 years, there was an idea that it had done its duty. If a rope were systematically recapped, and tested with satisfactory results, it seemed wasteful to take it off and consign it to the scrap-heap. He had a winding-rope which had lasted 4¼ years, and it was as good to look at as the day it was put on. He had tried a large number of rope-lubricants, and none of them had given satisfaction. Managers should refuse to receive any rope which was not properly covered, as ropes were often damaged before they reached the colliery, by being sent out of the works without a cover, becoming wet, and being put into stock, so that corrosion was going on before it was brought into use. He was inclined to think that a hempen core was more satisfactory than an iron one. He believed that abrasion was as dangerous as corrosion, and more difficult to detect; he had had wires laid before him, and he could not tell, until they were tested, that abrasion had been going on.

Mr. A. H. STOKES said that a good price might be paid for ropes, but was there any member present who could tell what material had been supplied for the money? He knew of a case of a steel rope, with a breaking strain of 72 tons, placed in a shaft which was perfectly dry; that rope broke within 16 months, through internal corrosion, although it had only been drawing about 300 tons per day. If internal corrosion started on the first day the rope was used, how long would that internal corrosion have to go on until the rope became unsafe? Many persons said, probably 2 years, and that was why they limited the life of a winding-rope to that period. He had tested ropes which had been in use for 2 or 3 years, and found that the torsion- and tension-tests were good; but in other cases he had seen wires, which had stood thirty-six twists when the rope was new, break with two or three twists, and that, as he had said, after less than 3 years' wear.

Mr. A. CHAMBERS thought that it would be a good plan if the ropes from the drum to the pulley-wheels were covered, as they were in France. If the rain and wet were kept off, the ropes would last longer.

ELECTRIC BLASTING.

By WM. MAURICE.

Part II.*

Evolution of Electric Fuzes.—Modern detonator-fuzes are divided into two classes, called respectively high-tension and low-tension caps. Since these terms have become almost universal, they must necessarily be retained in the present paper. It should, however, be remembered that the designations above mentioned are merely distinctive, and not explanatory, except in so far that the necessity for a slightly higher electric pressure in one case than in the other is thereby implied.

If the expression "high-tension," as applied to a particular class of fuzes, is taken to mean that a high electric pressure is required to bring about ignition, then the term is misleading. But considered relatively, and as indicating that a high-tension cap requires a higher electric pressure to overcome the resistance of its bridge than one of the class known as low-tension, then no doubt the terms are sufficiently accurate for practical purposes.

The two classes of electric fuze may perhaps be best defined in relation to the bridge or partially conducting medium, which is placed between the wire terminals in the fuze-casing, thus :—High-tension fuzes have terminal wires bridged by a chemical paste or powder of relatively high electrical resistance. Low-tension fuzes on the other hand have their terminal wires bridged by a metallic wire of relatively low electrical resistance. The origin of the distinguishing appellations by which the different types of fuze are recognized may be traced to the fact that, in the early days of electric blasting, exploders were either primary cells, giving a potential difference of only a few volts, or true high-pressure apparatus, such as frictional machines, induction-coils, or magnetos with condensers attached thereto. Any of the last-named appliances would set up very high potential differences, and actually spark across the fuze-terminals.

Probably this also accounts for the stereotyped explanation of the manner in which ignition is brought about in a high-tension fuze. It is usually

* Part I., *Trans. Fed. Inst.*, vol. xiv., page 142.

somewhat to the effect that "the high tension of the electricity gives it a capacity to send a spark across the small space between the points of two insulated wires of a fuze, which spark fires a sensitive chemical composition, and the latter in turn fires the fulminate." It may perhaps be observed that nothing of the kind necessarily occurs. Whether an actual electric spark passes through the fuze-composition depends altogether on the means taken to cause ignition.

The writer prefers to explain the ignition of high-tension fuzes in the following manner:—Premising that the fuze consists of two wire-ends placed within a short distance of each other, and embedded in a priming, the essential qualities of which are that it should be combustible and also a partial conductor of electricity, electrical energy at the fuze-terminals is, owing to the insufficient conductivity of the bridging-composition, converted into heat energy; the heat cannot dissipate with sufficient rapidity, therefore the temperature rises to the point of ignition of the bridge or priming, the latter bursts into flame, and ignites whatever explosive compound there may be in the casing.

Substituting "wire bridge" for "bridging composition," the same explanation applies equally well to low-tension fuzes.

Leaving for a while further remarks on modern caps, the writer will endeavour to indicate the stages through which each class of fuze passed before arriving at its existing state of efficiency, and to point out a few of the innumerable designs that have from time to time been produced. Some of the devices about to be described obviously never had any great practical value in themselves, yet, considered as steps on the way, they will serve to show that there has been at least "something attempted, something done," towards perfecting electric fuzes, more than is popularly supposed.

Low-tension Fuzes.—Low-tension fuzes were employed for the purpose of gunpowder ignition many years before the principle of detonation was applied to the explosion of nitro-glycerine and gun-cotton. The earliest of these gunpowder fuzes were generally similar in construction to that devised by Colonel Shaw, an American engineer, a perspective view of which is shown in Fig. 13 (Plate XXIII). It consisted of a small wooden box, provided with a cover turning upon a pivot. Two copper wires, insulated by having guttapercha tape wrapped spirally round them, were bared at their ends and passed through and through holes in the box, as represented in the figure. The terminals were spaced $\frac{3}{8}$ inch apart, and a fine platinum wire stretched across. By arranging the wires

in the manner indicated all strain was taken off the delicate wire-bridge, and the conducting wires themselves were effectually prevented from short-circuiting. The box was filled with fine dry grained gunpowder and the lid tied down : the completed fuze being then introduced into the charge to be fired, attached to the firing-line, and exploded by closing the electrical circuit through a group of primary cells.

Another old form, of lesser dimensions than that of Colonel Shaw, is shown in Fig. 14 (Plate XXIII.). Iron connecting-wires were used (being stiffer, therefore more easily manipulated, and less liable to damage in the operation of stemming), the two ends of which were thrust through two holes bored in a small cylindrical wooden plug. The bridge, composed of fine platinum wire, to which was tied a minute wisp of gun-cotton, was placed between the protruding points, and a wooden tube, filled with gunpowder, was fastened over the end, and water-proofed with cement, as shewn in the illustration.

Mr. Alphonse Dumas (Paris) constructed fuzes in 1864 with a $\frac{1}{4}$ inch fine platinum wire, joined across the ends of the firing-line. These were embedded in gun-cotton, powdered over with fulminate of mercury, and the priming so prepared was enclosed in a guttapercha pouch filled with gunpowder.

A great impetus was given to the development of electric fuzes by Mr. Nobel's discovery, in the same year, of the means of setting free the enormous energy of nitro-glycerine by the initial explosion of a detonator. In his British patent* he claimed the ignition of the explosive by "the elevation of temperature produced by an electric wire, or by an initiative explosion or detonation produced in various ways . . . ."

It may be observed incidentally that the familiar copper capsule, which forms so essential a part of a modern detonator, was not evolved without prolonged study of apparently insignificant details. The cap, however, forms no part of an electric fuze, and detailed consideration of its development does not therefore fall within the scope of this contribution. Indeed, it would be extended to a length altogether disproportionate to the general interest taken in the subject were the writer to enter into the experiments of Sir Frederic Abel, the Technical Committee of Austrian Engineer Officers, Mr. J. Paulus of Küppersteg, Messrs. Sellier & Bellot of Prague (Bohemia), and others, at home and abroad, on the form, material, and thickness of detonator caps.

The main results of these investigations may, however, be briefly noted as follows :—The substitution of small metallic cases for those of

* *Patent Specification*, 1864, No. 1,813.

wood or paper; the utilzation of fulminate of mercury in a compressed, instead of a loose, condition; and the admixture of certain oxidizing elements with the fulminate for the purpose of producing a variation in the detonating effect.

A Continental cap, introduced by Mr. Gérard, is represented in Fig. 15 (Plate XXIII.). The conducting wires in this fuze were tied together about ½ inch from their extremities, a platinum wire 0·2 inch in length was soldered across the tips, and the fuze-head prepared in this manner was then inserted in a paper tube *T*, which was then tightened round the insulation of the wires. Gunpowder was added at the outer end, a paper wad superposed, and the edges of the tube closed over all. The weak point in this fuze, namely the great length of unsupported wire inside the case, is obvious.

Mr. Chalon endeavoured to remedy this defect by designing the cap illustrated in Fig. 16 (Plate XXIII.). The conducting wires were carried along grooves in a piece of wood, and tied across the end. Insulation was then removed from the tips, the latter were flattened, bent back, and clamped on to a bridge of vegetable fibre, around which a spiral of No. 47 standard wire-gauge platinum wire was laid. The object of the fibre-thread was merely to facilitate the manipulation of this exceedingly delicate conductor. The fuze-head was inserted in a paper cylinder *T*, a priming of nitro-cellulose and powdered retort-carbon added, and the whole was enclosed in a detonator-case, *DC*, containing fulminate *F*. A covering of guttapercha, *C*, served to preserve the damp absorbent portions from injury due to this cause.

A Siemens cap of old construction is represented in Fig. 17 (Plate XXIII.). The bared ends of the conducting wires were cast in a plug of sulphur, *PL*, which exactly fitted a paper cylinder *T*. The platinum bridge, *Br*, was embedded in a mixture, *P*, of gun-cotton and gunpowder.

Descriptions of other low-tension fuzes might be continued almost indefinitely, so numerous have been the modifications in details, but it would serve no useful purpose to continue further in the same groove.

Clearly, the most important part of a low-tension fuze is its bridge, and here again the mining community are greatly indebted to Sir Frederic Abel for the invaluable researches which resulted in the production of a suitable wire. In consequence of difficulties experienced in the special application of high-tension fuzes to submarine purposes, the production of comparatively sensitive low-tension fuzes, of much greater uniformity of resistance than those employed in former years, was made, by Sir Frederic Abel, the subject of an elaborate experimental investigation.

Experiments instituted with platinum wires, much finer than those hitherto used in the construction of fuzes, demonstrated that wires made of different specimens of commercial platinum varied very greatly in electrical conductivity. As these variations might be due to two causes, or combinations of them, namely, a difference in the purity and in the physical condition of the metal, the matter was investigated in both directions.

It was found that very considerable differences in the amount of forging to which the metal, in the form of sponge, had been subjected did not affect to any important extent either its specific gravity or its conductivity, and that the fuzed metal had only a very slightly higher degree of conductivity than the same sample forged from the sponge. It was therefore clearly established that the conductivity of such very fine wires as it was proposed to use in the construction of fuzes was but slightly affected by physical peculiarities of the metal of which they were composed, and that the considerable differences in conductivity observed in different samples of platinum were ascribable to variations in the degree of purity of the metal. As it appeared likely, therefore, that more uniform results would be attained by the employment of some alloy of definite and uniform composition as the bridge for low-tension fuzes than by the use of commercial platinum, varying considerably in composition, experiments were made with fine wires of German silver (which had been used by a wellknown American electrician, Mr. Farmer, in the construction of comparatively sensitive wire fuzes), and of the alloy of 66 of silver with 33 of platinum employed by Matthiessen for the reproduction of British Association standards of electrical resistance.

It was found that both these alloys were greatly superior to ordinary platinum in regard to the resistance opposed to the passage of a current, and the heat consequently developed in given lengths of wire of a particular diameter, and that German silver was in its turn superior in this respect to the platinum-silver alloy: although the difference was only trifling in the small lengths of wire used in a fuze (0·25 inch).

On the other hand, the comparatively ready fusibility of a platinum-silver wire contributed, with other physical peculiarities of the two alloys, to reduce fine German silver wire to about a level with it.

Moreover, German silver was found not to resist the tendency to corrosive action exhibited by gunpowder and other more sensitive explosive agents, which have to be placed in close contact with the wire bridge in the construction of a fuze, so that the latter may be at once fired when the required heat has been developed by the resistance which the wire bridge offers to the current. Platinum-silver on the other hand was found to remain unaltered under corresponding conditions of exposure.

The superiority of platinum-silver, and even German silver, as a material for the bridges of fuzes, appeared, therefore, to be established from a practical point of view; but, as some difficulties were apprehended by the manufacturers in the uniform production of a silver alloy, containing the large proportion of platinum essential to furnish the high-resistance wire required, experiments were made with alloys of platinum with definite proportions of iridium, the metal with which it is chiefly associated; and eventually very fine wires of an alloy containing 10 per cent. of iridium were selected as decidedly the best materials for the production of wire-fuzes of comparatively, and very uniform, high resistance, this alloy being found decidedly superior in the latter respect, as well as in point of strength (and therefore of manageableness in the state of very fine wire, 0·001 inch in diameter) to the platinum-silver wire.*

* "Electricity applied to Explosive Purposes," by Sir F. A. Abel, *The Practical Applications of Electricity: A Series of Lectures delivered at the Institution of Civil Engineers*, 1882-83, pages 131 to 133.

It is thus seen that the delicate bridge now employed in the construction of low-tension fuzes, which is usually of the nature and dimensions given above, was not obtained haphazard, but was the outcome of many failures and of a protracted course of searching experiments.

Improvements in other details of construction have long received the attention of manufacturers and experimentalists, as will be gathered from the particulars given below of some low-tension fuzes devised during the past 14 years. In 1883, Messrs. Mackie & Warburton proposed to apply their "invicta" fuzes more effectually to the firing of compressed charges of gunpowder or other explosives, by forming the two conducting wires into a loop on each side of the fuze, which was turned back towards them and secured by cord or otherwise, "so that on ignition it might deliver its fire backwards into the charge to which it is secured, and so that the obstruction of the loop would prevent the withdrawal of the fuze from its proper position in the charge, and at the same time protect the fuze itself from injury."

The special objects aimed at in Messrs. Macnab and Hickie's fuzes, which were introduced 2 years later, were greater certainty of action, more freedom from damage, and better contact between the poles, besides neutralizing any chemical action that might take place between the priming composition and the substance of which the plug or wire-holder case was composed. The low-tension fuze was constructed in the following manner :—A glass tube *T* (Fig. 18, Plate XXIII.), open at each end, was made to fit into a copper detonator-case *DC*, the flange or lip serving to prevent the plug from being forced into the fulminate of mercury, *F*, contained in the cap. The two connecting-wires were cut to the required lengths, inserted in the glass tube with their terminals projecting beyond the end, and then cemented in with Spence metal (Portland cement and sulphur). After this composition had set hard, the terminals were cut to the required length and prepared for bridging. For this purpose, a slot or eye was made in each terminal at the extreme point, the platinum wire inserted therein, nipped with pliers, and then either soldered or touched with shellac varnish. The fuze-head so constructed was next dipped into a non-conducting inflammable varnish, so that there would be no liability to short-circuit in the event of the terminals accidentally coming in contact with the copper cap. When these fuzes were intended for simple ignition, an outer case of glass was substituted for that of copper, and charged with dry fine-grained gunpowder.

A German inventor, Mr. Gustav Bloem, proposed, in 1885, to make the bottom of detonator-caps weaker than the sides, in order to concentrate the effect of explosion.

The American fuze-head of Mr. H. Julius Smith, which is illustrated in Figs. 19 and 20 (Plate XXIII.), was introduced in 1886. The particular feature of this cap is the provision made for holding the terminal wires rigidly in place in the fuze-casing. Fig. 19 represents a longitudinal section showing the cylindrical casing *T*, having a bead *B*, for holding the fuze-head securely in position. A clamp *Cl* formed of a strip of sheet metal, embracing the wires and bent over upon itself, serves to maintain an immovable head, which carries the usual fuze-wire *Br*. The latter is imbedded in priming and capped with a disc *D* of meal-powder. It is interesting to note that the bulk of the low-tension detonators supplied by the Roburite Company, Limited, of Gathurst, near Wigan, have fuze-heads constructed upon the American plan.

Another form of fuze-head, also designed with the object of definitely fixing the position of the terminal wires and preventing any possibility of shunting the bridge in process of manufacture, is seen in Fig. 21 (Plate XXIII.). To prepare these fuzes, the connecting-wires of No. 24 standard wire-gauge, tinned-copper, twin-insulated, are bared for a length of about 1 inch, the bared wires being then laid in grooves at each side of a small cylindrical wooden plug *Pl* (Fig. 21), with their extremities overhanging just sufficiently to solder thereto a bridge, of standard alloy and dimensions. A paper strip is rolled round this plug to form a cylinder, rather longer than its support, and of an outside diameter approximating to that of the detonator-case. The latter is of copper, and contains a definite charge of fulminate as in all other detonators, according to the class of explosive with which it is intended to be used. The fuze-head after being charged with priming, and sealed, is pushed into the detonator-case and retained there by slight indentations made in the metal. The usual waterproof luting round the opening of the case completes the fuze, which (like that last described) finds extensive application at the present time.

The low-tension fuze designed by Mr. Dumas (Paris), in 1887, and shown in Fig. 22 (Plate XXIII.), is to some extent a departure from those previously described. It is characterized by the application to the platinum bridge of an impervious varnish exploding under a low temperature. This varnish preserves the contacts from oxidation and thus ensures the perfect conductivity of the wire for an indefinite time. The varnish, which usually consists of collodion, ignites at a temperature of

about 240° Cent.,* so that an extremely feeble current of electricity passing along the wire suffices to cause explosion of the fuze. For blasting-powder ignition, the fuze-head is introduced into a pasteboard tube, *T*, (Fig. 22), which is subsequently filled with gunpowder, then plugged, and the extremities of the case turned down. When the fuze is to be used with high explosives a detonator-cap is added, and the finished fuze is dipped into collodion varnish.

Fig. 23 (Plate XXIII.) illustrates the manner in which the Nobel low-tension detonator, now so extensively used in collieries, is constructed. A metallic case *DC* contains a mixture of fulminate of mercury and potassium chlorate. A pair of insulated connecting-wires, No. 24 standard wire-gauge 48, 54, or 60 inches long, are twisted together from one end for a distance of about 3 inches, and a fuze-head is formed on the extremities approximately in the following manner :—The insulation is pressed back and the wire tips are tinned with solder, after which a bridge of platinum-iridium wire 0·001 inch in diameter and 0·25 inch long is attached thereto. This bridge is inserted in, and cemented to one end of a small paper cylinder *T*; meal-powder † being added at the opposite end, until it entirely covers the bridge and fills the casing. A wrapping of gold-beater's skin or similar damp-protecting medium completes the head which is then inserted in the detonator-case, and cemented or varnished in the ordinary manner. The entire fuze is afterwards dipped into sealing-wax varnish as far as the twisted portion of the wire extends.

The Manet fuzes, manufactured by Messrs. Manet, Gaupillat et Compagnie (Paris) are more elaborate. Two patterns are illustrated in Figs. 24 and 25 (Plate XXIII.), in either of which will be noted a cardboard tube *T*, in which is placed a support *PL*, of hard wood, vulcanized fibre, or other insulating material, having attached thereto a pair of screws for mechanically and electrically connecting the conducting-wires with the platinum bridge *Br*. This is covered with priming as usual, and sealed with a disc *D*. When required to be used as a detonator, a copper casing *DC*, containing fulminate, is placed over the disc.

Mr. Linke, of Charlottenburg, has introduced during the past year a fuze that in principle at any rate carries one back to early days. An ordinary fuze-head, as represented in Fig. 26 (Plate XXIII.), is wrapped

* Red heat, just visible, has a temperature, according to Prof. Pouillet, of 977° Fahr. or 525° Cent.

† The finely powdered and mixed constituents of gunpowder.

about with highly nitrated cotton-wool, thereafter being immersed in collodion. The platinum bridge consequently does not come into contact with the collodion, but acts directly on the gun-cotton, which constitutes the priming charge.

Prof. F. Jervis-Smith, director of the Millard Engineering Laboratory, Trinity College, Oxford, is engaged in perfecting a novel form of detonator, the general appearance of which may be gathered by referring to Fig. 27 (Plate XXIII.). A number of patterns have been designed, that illustrated being the one suggested for use in mines in 1894. Prof. Smith recognized the serious risks run by those who have regularly to handle cases containing fulminates, and therefore addressed himself to the production of a detonator free from this particular element of danger. The professor claims to have discovered that if a small quantity of gun-cotton be placed in a suitable vessel, and the air contained therein suddenly compressed, sufficient heat is generated to cause detonation of the charge. This principle is adopted in the detonator under consideration. The component parts are : a detonator case *DC* (Fig. 27, Plate XXIII.) containing a proper quantity of explosive *GC*, and a plunger *D*, together with a platinum igniting-bridge *Br*, embedded in a gunpowder priming *P*. Ignition of the latter charge is effected according to any customary method, whereupon its explosion drives forward the piston or plunger *D*, compressing the air around the gun-cotton, and thus causing its detonation. In order to obtain the advantages of adiabatic compression, the piston *D* and cylinder *DC* are made of glass, vulcanite, vulcanized fibre, or other non-conductor of heat. The end of the cylinder is preferably made the weakest part, in order that it may be the first to give way.

High-tension Fuzes.—The first stage in the development of the high-tension or spark fuze, as it was originally called, wherein two pointed wires were set a short distance apart in a wooden or metallic case and covered with gunpowder, has been already detailed.*

With the application of the Ruhmkorff coil in 1851 for blasting purposes, there arose the necessity for improvements in the class of fuze now about to be considered. Colonel Verdu, a Spanish engineer officer, to whom reference has previously been made, was one of the earliest investigators in this field. Colonel Verdu, in collaboration with Mr. Ruhmkorff, experimented with various substitutes for gunpowder as a priming, such as gun-cotton, mixtures of sulphur and potassium chlorate,

* Part I., *Trans. Fed. Inst.*, vol. xiv., page 145.

fulminate of mercury, etc., and ultimately decided that the last-named compound was by far the most sensitive preparation.

Captain Savare, a French military officer, also devoted considerable attention to improvements in the construction of fuzes, in order that they might be rendered more serviceable in simultaneous group-firing. He employed wires tipped with Darcet alloy, surrounded by a priming of gun-cotton enveloped in a piece of inflammable cloth.

The real origin of the modern high-tension fuze is, however, associated with the first submarine telegraph cable, namely, the Dover-Calais, laid down in September, 1851. A fault which occurred during its construction necessitated special testing, and this operation happily served to indicate the lines along which developments in high-tension fuze construction might be expeeted.

Comte du Moncel gave an account of this discovery in 1857,* but the information given by Sir Frederic Abel† is more detailed and particularly interesting :—

> In August, 1851, a length of copper wire which had been covered at the Gutta-percha Company's works with guttapercha, containing about 10 per cent. of sulphur, was being passed through water from one reel to another for the purpose of discovering what appeared to be a fault in insulation, when suddenly a bright spark was observed in the water. On examining the wire at that particular spot it was found to be broken, and the guttapercha burnt.
>
> Several pieces of similarly covered wire were then purposely broken, in each case with similar results. A length of the guttapercha was then removed from the wire, and on applying the two poles of one hundred cells of the battery in use at various distances to the inner surface, which had been in contact with the copper, and had become coated with a film of sulphide of copper, which in comparison to copper is of very high resistance, heat was generated in proportion, of course, to the distance of the poles. Gunpowder was placed upon the guttapercha, and on applying the battery-poles it was immediately ignited. Consequently, by removing a small portion of the guttapercha from the upper surface of the wire, then severing the latter at that point, and slightly separating the two extremities, a suitable fuze for igniting explosive substances at long distances, and simultaneously at several points, was produced.

Fuzes constructed in this manner, of which one specimen is illustrated in Fig. 28 (Plate XXIII.), were named after Messrs. Statham & Brunton, who were the first to produce them. Colonel Verdu employed Statham fuzes in his experiments at La Villette (Paris) in 1853, and in the following year they were tried upon a somewhat extended scale in the blasting operations necessary for the construction of the harbour of Cherbourg.

When, in 1856, experiments were made at Woolwich with the Henley

* *Exposé des Applications de l'Électricité*, by Comte du Moncel, vol. iii., pages 288-9.

† Sir F. Abel, *op. cit.*, pages 115-116.

large magneto-machine, it was found that the induced current obtained would not ignite, with certainty, a single charge of gunpowder. Statham fuzes gave fairly good results, and another fuze prepared by Mr. Henley proved even better, but the nature of the latter was never disclosed.

Sir Frederic Abel and Mr. E. O. Brown, of Woolwich, thereupon undertook a long and painstaking investigation, extending over 11 years, into the conditions to be fulfilled in the production of a fuze which should be certain of ignition by the magneto-machine, and eventually they found that a combination of comparatively high conducting power with great susceptibility to ignition were essential elements of success in the preparation of a priming material for such fuzes. The uniform arrangement of the wire terminals in the fuze, the space between which was to be bridged over by the igniting composition, also proved a matter of great importance. This point was secured by enclosing two fine copper wires side by side in guttapercha.

A fairly efficient fuze was obtained, with the aid of the poles thus arranged, by employing as the igniting agent gunpowder impregnated with a small proportion of calcium chloride, which caused it, on brief exposure to air, to imbibe moisture sufficient to render the gunpowder highly conducting. It is obvious, however, that there must be a liability to want of uniformity in the proportion of water absorbed by the powder, and a consequent variation in the conducting power of the latter. Eventually a material was prepared (consisting of the subphosphide of copper, subsulphide of copper, and potassium chlorate) which combined the essentials of perfect certainty of action with very great sensitiveness to ignition.*

The principle of bridging the wire terminals of a fuze with a partially-conducting chemical composition susceptible of inflammable decomposition upon being electrically heated, thus developed by Sir Frederic Abel, forms the basis of all those fuzes now called high-tension in this country, and divides high-tension fuzes into two distinct classes :—One class answers to the description already given ; the other consists of those fuzes that have a priming of very great electrical resistance, which can, in fact, only be ignited by causing sparks to pass from point to point. These spark or true high-tension fuzes, have practically died out of use in Great Britain, but in Continental Europe generally they are probably used more extensively than any other variety.

Some early types of Abel fuze are illustrated in Figs. 29, 30, and 31 (Plate XXIII.). Fig. 29 shows one of the patterns in vogue prior to the development of the copper-salt priming. Bare copper conductors, of No. 25 standard wire-gauge, were encased at their ends in Chatterton compound, *C*, a sheet of tin being then rolled round the insulating material

* *Op. cit.*, page 119.

to form a cylinder, which was secured thereto by a number of circular corrugations. The wire tips were separated by an air space of 0·04 inch, which was subsequently filled with a priming-mixture, composed of chlorate of potash, phosphorus, and charcoal. This fuze was only 0·15 inch in diameter, and 0·75 inch in length, it being intended in this form simply for gunpowder ignition.

Another design, wherein an attempt was made to preserve the conducting wires from any tendency to displacement in the fuze-head, is shown in Fig. 30. A small Abel fuze, of the construction indicated in the last illustration, contained the priming composition *P*. This cap was placed in a detonator-case *DC*, and the whole was fixed securely in a wooden cylinder *T*, having a hole bored through it longitudinally, of two different diameters, suited to the respective dimensions of the conducting wires and detonator-cap. The coned end was filled with pitch, in order to secure the wires and make the casing damptight.

Fig. 31 (Plate XXIII.) shows a third pattern of Abel fuze, having the improved arrangement of terminal wires, already referred to. A short piece of the specially-prepared twin wire was soldered to the ends of the copper conductors, and the head, so formed, inserted into a paper tube *T*, which was afterwards filled with the conducting primer, composed of copper salts and potassic chlorate, upon which so much research had been expended.

An interesting fuze was devised by Mr. Beardslee, of New York, in 1863. In construction it was simple in the extreme, consisting of nothing more than a small plug of bass wood, as represented in Fig. 32 (Plate XXIV.), in which two No. 16 standard wire-gauge copper wires were inserted 0·18 inch apart from centre to centre. The wire-ends were filed off flush with the wood surface, and a conducting bridge formed by drawing a graphite pencil-mark from wire to wire. A paper tube *T*, rolled round this plug, held a small charge of fine-grained gunpowder in contact with the feeble conducting streak. A Beardslee exploder, wherein the magnets were made to revolve between the armature-coils, was employed to fire these fuzes.

Two spark-fuzes, as formerly made by the various European Nobel Companies, are shown in Figs. 33 and 34 (Plate XXIV.). The first pattern (Fig. 33), indicates two No. 22 standard wire-gauge conductors, separated at their extremities by a space of 0·01 inch, and rigidly fixed in a plug of sulphur. A brass tube *T*, surrounded the terminals, which were, of course, embedded in priming. A small package of fulminate was superposed, and the tube-end sealed with shellac.

In the second pattern (Fig. 34), the same gauge of wire was employed, but it was insulated with guttapercha, and a fuze-head was formed by twisting the wire ends and wrapping them round with cotton to the diameter of the detonator-cap. The extreme tips were bared, and pushed into the priming *P*, which lay in contact with the charge of fulminate *F*. With the object of making this cap suitable for sub-aqueous blasting, tubes *T'*, *T''* of caoutchouc were slipped over the wires and partly inserted into the detonator-case, where they were fastened by cement *C*. An outer rubber tube *T*, enveloping a portion of both cap and wires, was finally put on, and tied as shown in the illustration.

An Austrian fuze, Fig. 35 (Plate XXIV.), used with the Ebner frictional exploder, had a priming-mixture composed of potassium chlorate, potassium ferrocyanide, charcoal and sulphur or sugar, placed over the terminal wires, which were, as in some of the examples already given, merely the ends of the connecting-wires fixed in a small cylindrical block made of sulphur and powdered glass. A disc of pulped gun-cotton and a charge of mercuric fulminate enclosed in a copper cap, were added if required to detonate high explosives.

Captain McEvoy's fuze, produced in 1873, was substantially the same as that last described. Two conducting-wires were placed in proximity to, and parallel with each other, and a sulphur compound cast around them in a cylindrical or other suitably shaped mould. The ends of the wires from one end of the insulating support passed to the source of electricity. The ends projecting from the opposite extremity of the casting were cut off flush with the end, and a long metal cap containing fulminating material was slipped over the terminals. The joint between the metal and the support was rendered watertight by the application of shellac varnish or otherwise.

One of the fuzes designed by Mr. S. Mackie is shown in Fig. 36 (Plate XXIV.). The fuze-heads were made as indicated above, but in order to ensure greater safety in storage soft metal caps containing priming were only added when the fuzes were required for service. A fuze with the soft metal cap attached was suitable for gunpowder ignition. To effect detonation, the same fuze was inserted in a copper detonator-case containing fulminate.

In the same year (1873), Mr. W. B. Brain proposed to construct electric fuzes by "enclosing within a paper or other tube on the end of the conducting wires any known composition which becomes incandescent under the action of an electric current." The paper tube was preferably rolled upon the insulating-material of the conducting wires, but might

be previously moulded and then slipped on and cemented in position. A charge of priming was next put into the space formed by the projecting end of the tube, and covered by a metal cap which exactly fitted it. The interesting point to be noted in connexion with Mr. Brain's fuze is that after an interval of 24 years the same description substantially covers the method adopted in the manufacture of a very great proportion of the detonator-fuzes now used.

About 8 years later, Messrs. Johnson & Spon sought to render fuzes more certain of action by arranging the terminal wires in such a manner as to obtain a double spark. Reference to Figs. 37, 38, 39, 40, and 41 (Plate XXIV.) will show how this effect was obtained. Two wires were twisted together as shown in Fig. 37, an untwisted portion about ½ inch in length being left in the centre. The wires were doubled over at the untwisted section, cemented in a small tube *T*, and the loops were filed off (Figs. 38 and 39). Side and end views of the fuze then presented the appearance seen in Figs. 40 and 41, indicating the main wires and the subsidiary wires intended for dividing the sparks. The wires were joined across these ends with plumbago lines, and the electrical resistance adjusted by removing particles of graphite, while the conductors formed part of a galvanometer circuit.

Messrs. Macnab & Hickie's high-tension fuzes are prepared in much the same manner as the low-tension variety,* but instead of the platinum bridge a chemical priming is placed over the terminals in the interior of the glass plug-case and closed with a disc of cardboard, which has been dipped into an inflammable composition. The finished fuzes are immersed in a bath of sealing-wax varnish or guttapercha cement, in order to protect the interior priming from water or climatic influences (Fig. 42, Plate XXIV.).

Abroad, fuzes designed by Messrs. Abegg, Scola, Breguet, Gaiffe, and many others, have been at times more or less extensively employed for blasting purposes. It will suffice to describe the two first-named. In the construction of the Abegg cap, the conducting-wires were stuck through a piece of card, and their extremities bent and laid opposite to each other, separated only by a space of 0·04 inch. Priming was placed over the ends, and the entire head was wrapped round with a band of paper. This fuze was, as usual, inserted in a cap containing a charge of fulminate.

So called "blasting-sticks," arranged somewhat as shown in Fig. 43 (Plate XXIV.), were often used in conjunction with these fuzes. They

* *Trans. Fed. Inst.*, vol. xiv., page 450.

were simple laths, 3 or 4 feet in length, to which the detonator and wires were attached. The rigidity of the stick allowed the fuze to be readily pushed into the bore-hole. When the ground was not very wet, bare wires were, for cheapness, used, and the stick was in that case covered with oiled paper, or some substance capable of resisting moisture.

The fuze-head of the Scola cap was simply constructed, and yet very sensitive. A small cylinder of wood (0·16 inch in diameter and 0·5 inch long), having a saw-cut along opposite sides in the direction of its length, served to support two No. 27 standard wire-gauge silk-covered copper wires. These were laid side by side, along one groove, across the end, and back to the starting-point, at which place they were secured. The sparking gap of about 0·04 inch was formed by removing a small portion of insulation from the wires at the base of the plug. Priming, composed of potassium chlorate, sulphide of antimony, and retort-carbon, was pressed tightly into a paper tube surrounding the plug. The terminal wires were then soldered to stouter connecting-wires, and the joints were covered with insulating and waterproof cement. A detonator-cap was attached, if needed, by affixing to the fuze a cardboard sleeve, from 2 to 2½ inches in length, and of such a diameter that a cap of standard dimensions might be slipped inside.

The Scola company have also produced a curiously round-about invention denominated the Ruggieri fuze. It is specially intended to be used "in coal-mines liable to the presence of fire-damp," and is merely a lighter for igniting ordinary tape-fuze, which latter in its turn fires either a powder charge or a detonator. This fuze is composed of a grooved wooden plug *PL* (Figs. 44, 45, and 46, Plate XXIV.), embraced by the insulated conducting wires *W*, which are first twisted together at the inner end of the plug, then laid in the grooves *G*, and twisted again at the opposite end as shown. The wires at the inner end of the plug are then flattened down. The plug is enclosed in a paper sheath *T* (Fig. 47), a charge of fulminate being filled into the space *P* at the closed end of the sheath. The electric fuze is introduced into a tube *T'* (Figs. 47 and 48, Plate XXIV.) of copper or pasteboard, provided with tape-fuze, which is ignited and projected by the fulminate into the bore-hole, and fires the charge placed therein.

In the year 1886, Mr. G. Smith effected a notable improvement in the construction of high-tension fuzes, reducing them to perhaps their most simple form by dispensing with all paper tubes, wooden plugs, or other devices of like nature, and applying a priming composition direct to the tips of the conducting wires in the form of an adhesive paste.

The Nobel Company's wellknown reliance and standard high-tension fuzes are made in this manner, as shown in Fig. 49 (Plate XXIV.).

In 1889, Mr. Paul Ward introduced a series of fuzes specially adapted for use in damp tropical regions, or, in fact, all places where climatic or local influences tend to bring about deterioration in fuzes of ordinary construction. In the preparation of a high-tension fuze, two bare wires *WW* (Fig. 50, Plate XXIV.), are inserted in a glass tube *T*, special means being provided for maintaining their ends a standard space apart. The tube-end next the wire terminals is then heated in a blowpipe flame, thereby causing the glass in its semi-molten state to completely surround each of the free ends of the wire and insulate them from each other. By this process, the conducting-wires are fixed in an insulating support and a tube for containing priming-material, both obtained at a single operation. The priming (which is composed of carbon, sulphur, amorphous phosphorus, and potassium chlorate, intimately mixed in definite proportions with alcohol, benzol, and carbon disulphide into a creamy mass) is next placed in the fuze-casing to the weight of 0·2 grain. The charged tube is subjected to a temperature of about 212° Fahr. in order to drive off the volatile portion of the composition, after which a detonating charge, consisting preferably of gun-cotton, is added; then a plug of slag-wool or other non-combustible material is inserted, and the tube is hermetically sealed over all.

The Electric Blasting Company, of Cinderford, have taken an active part in the development of electric blasting during considerably over 20 years, and have effected numerous improvements in details from time to time. Their latest pattern of fuze-head is designed in such a manner that the conducting-wires cannot be easily pulled out of the cap. With this object, the bare ends of the leading-wires are passed through a small insulating disc of wood, ebonite, or other suitable substance, and are turned back over the top, and also, if desired, down the sides of the disc. The back of the disc is coated with an insulating composition, and in some instances the leading-wires near the disc are surrounded by a short tube of paper or wood. The fuze is enclosed in an outer casing, leaving room above the disc for the explosive material, which is covered by a plug.

The ball-fuze of Messrs. Manet, Gaupillat, et Cie (Paris), devised about 3 years ago, will be seen from a brief reference to Figs. 51 and 52 (Plate XXIV.) to constitute a somewhat novel form of igniter. It differs from both high and low-tension caps of ordinary construction, in its manner of causing ignition, though in accordance with the writer's

definition, it is here classed as a high-tension fuze. It is wellknown that if an electric current is passed through two masses of carbon, or other conducting substances terminated by points slightly rounded and arranged in contact in front of one another, the resistance experienced by the current causes a considerable elevation of temperature at the points of these two contacts. In this *amorce à boules*, the heat thus developed is utilized either by surrounding the two heated points with an inflammable substance, or by forming the two contacts themselves of a substance which is both a conductor of electricity and inflammable at a certain temperature. The fuze-head is formed of a small core *PL* (Fig. 51), of cardboard, in which two insulated wires *W*, *W*, are fixed. The two uncovered ends of these conductors extend slightly beyond the core, and are terminated by two little spatulas formed by flattening the wire-tips. In order to solidly fix the conducting wires the core ends in a kind of dish, which is filled with wax ; this also tends to ensure a damp-proof interior. The spatula-shaped tips support two small ovoids composed of potassium chlorate, sulphide of antimony, and sulphide of copper, mixed together in certain proportions. The two latter chemical compounds provide the desired electrical conductivity, the object of adding potassium chlorate being to furnish the oxygen necessary for combustion. The conducting-wires in the fuze-head act as springs, and maintain the two ovoids in contact with each other. A fuze prepared as described is inserted in a casing-tube *T*, wherein it is solidly fixed by means of a bezil. This tube contains a small quantity of priming *P*, in contact with and surrounding the terminal wires. A plug *D*, covered with goldbeater's skin, is pressed into the casing-tube as far as the circular internal projection formed therein. The fuze, such as has just been described, serves for firing ordinary powder charges. When it is a question of blasting by means of high explosives necessitating the use of a detonator, this latter is placed at the end of the casing-tube, either in the inside or outside, and is fixed in position by any appropriate setting. When the wires of one of these fuzes are connected with a suitable source of electricity, the current meets with great resistance in passing through the imperfect contact existing between the two spheres, and consequently this part becomes heated, causing the ignition of the ovoids, which communicate the flame to the powder surrounding them, and the latter projects its flame through the hole in the disc *D*, either into the powder charge or on to the fulminate of the detonator.

Fig. 53 (Plate XXIV.) shows Mr. George Pettinger's recent development in fuze-head construction. A tube *T*, of a size to fit an ordinary

detonator-cap, is made of wood, porcelain, or other insulating material having a tapered bore. In this tube, the conducting-wires, with ends bared, are secured by first threading through the narrow inlet, then doubling at a suitable distance from the ends, and finally drawing back in such a manner that the bent portion thereof jambs in the tube. The size of the bore is such that the bent portion of the wires jamb at or near the middle, so leaving space for the introduction of the necessary priming, which is composed of copper salts, precipitated silver, bismuth, plumbago, and chlorate of potassium in suitable proportions. The fuze-head so constructed is secured in a detonator-cap in the usual manner.

The writer will have some remarks to make in another section of this paper bearing upon the necessity for great caution in handling detonators.

Some three or four years ago, Messrs. Hickie & Beutner patented the use of celluloid discs for protecting the fulminate in detonator-caps. It is obvious that such a device might also protect the fingers of those who are fond of exploring detonators at the point of a pin. Meanwhile, the very serious risk involved in attempting to withdraw fuze wires from detonator caps without the use of special apparatus for rendering an accidental explosion harmless, cannot be too strongly urged.

The remarks of Mr. M. Eissler, in the 1897 edition of his *Hand-book of Modern Explosives*,* on this head are terse, and to the point, and may therefore fittingly conclude this section on electric fuzes: "If you value your fingers and do not want to lose them, do not go 'fooling with the cap' because you want to see 'what is in it' or 'what it is made of.'"

Selection of Igniters and Detonators.—Electric ignition is applicable to every class of explosive, though of late years it has been employed chiefly as a means of exploding a detonator, which, in turn, effects the explosion of a blasting-charge.

The advantages, as regards safety in fiery and dusty mines, of employing only those explosives which can be fired by means of a detonating primer are not at all self-evident, and do not yet appear to have been clearly demonstrated. This, however, properly belongs to a discussion on the application of explosives, not of primers, with which the writer is now concerned. Leaving alone, therefore, the choice of explosive, it is desirable that attention should be drawn to the by no means uncommon practice of employing one size and make of detonator for initiating the explosion of blasting-charges possessing widely varying characteristics, thus frequently causing only partial decomposition of the charge.

Different explosives explode in different ways, as is wellknown; the

* Page 208.

complete dissociation of a given charge being only effected when, *ceteris paribus*, its explosion has been properly initiated. It is also a point of common knowledge that the explosive effect is a function of the speed of combustion, and thus the different explosives form series passing from a stage bordering on ordinary combustion to a stage of true detonation.

As bearing on the strength of detonator required for any explosive preparation, it would appear that the resistance of an explosive (when made up in its usual cartridge form) to the initiation of that almost instantaneous combustion or resolution into the gaseous state which is called detonation is roughly proportional to its chemical stability. Thus, blasting-powders of the same class as gunpowder, being composed of very stable substances, can only be detonated with extreme difficulty, probably not at all, under the ordinary conditions of blasting.

Under these latter circumstances the application of a detonator merely serves to increase vastly the rapidity of combustion of a powder charge, and consequently to intensify its disintegrating effects.

The cap designed by Mr. G. G. André, for the purpose of exploding powder in this manner, is doubtless familiar to all the older generation of mining engineers. It consisted of a stout brass casing, of comparatively large dimensions (§ inch in diameter and 1 inch long), one end being solid, except for a small hole to receive an electric fuze, and the other end entirely closed with a brass disc. A tube in which the fuze was placed was equal in length to the brass case, and when pushed through the hole above mentioned reached to the bottom thereof, being split on one side to allow the gases from the fuze to ignite the fine-grained powder with which the case was charged. Being strongly enclosed, the gases developed considerable pressure before coming into contact with the blasting charge, and thereby brought about the required rapid ignition.

It is not suggested that experiments on the rapid ignition of gunpowder be renewed, for since the wedging and gradual disintegrating action, which it is specially desirable to preserve, decreases in proportion to the closeness with which explosive decomposition approaches true detonation, any supposed gain in one direction is lost in another.

Noting, however, that the objections to the use of powder in mines apply equally, if not primarily, to the spitting fuze, it would appear that the application of a high-grade powder, waterproofed, tamped with damp clay, in a wet bore-hole, and fired by means of an electric fuze (not a detonator, be it noted), would overcome in a great measure all the objections that are usually urged against any explosive, when fired according to present practice.

The next class of explosive in order of susceptibility to detonation are the nitro-cotton preparations, of which tonite is the principal representative. No nitro-cotton compounds are at present (October 2nd, 1897) on the Home Office list of permitted explosives, but they find extensive application in tunnelling and quarrying operations. Detonators for this class require to be of a specially strong character, and usually contain gun-cotton: the explosion of tonite is due to detonation of the whole of the charge.

The nitrated hydrocarbon class of explosives at present on the permitted list are ammonite, bellite (Nos. 1 and 3), dahmenite, electronite, roburite, and westphalite. The explosion of ammonite, bellite, dahmenite, and roburite approaches true detonation; that of electronite and westphalite coming lower in the series. The explosion of this class can only be effected by the application of intense shock, the most suitable fulminating mixture being determined in each case by the manufacturers. The minimum (but no maximum) weight of fulminate to be used with any given explosive is laid down by the Explosives in Coal Mines Order, 1897, but the instructions there given are purely arbitrary, and make no specific reference to the composition of the fuze-priming or fulminate. For this reason it is desirable, while adhering to official instructions, to employ the make of detonator recommended by each individual firm for their explosive.

In order to obtain the lowest explosion-temperature, the fulminate should not be mixed with any free oxidizing compound.

There are three nitro-glycerine preparations now available on the permitted list, viz., ardeer-powder, carbonite, and kynite. They require to be detonated in order to develop rapid and powerful explosive waves. Fulminate, containing from 25 to 30 per cent. of potassium chlorate, is preferably used, nitro-glycerine mixtures being more completely decomposed when extra heat is added to that produced by simple detonation.

REFERENCE TO PLATES XXIII. AND XXIV.

Plug, or insulating support	*PL*	Bead or bezil	*B*
Cap or tube	*T*	Clamp	*Cl*
Conducting-wires	*W*	Disc	*D*
Fuze-wires	*FW*	Waterproofing cement	*C*
Bridge	*Br*	Fulminate	*F*
Priming	*P*	Gun-cotton	*GC*
Detonator-case	*DC*	Point	*X*
Grooves	*G*		

The meeting then terminated.

G. 17.

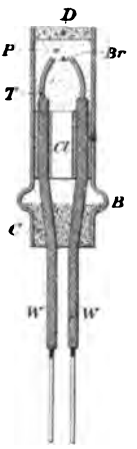


Fig. 19.

Fig. 20.

Fig. 18.

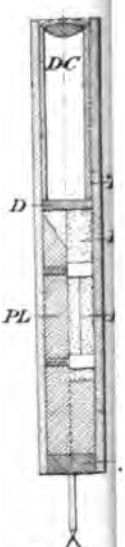


Fig. 2

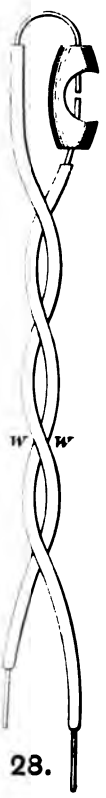


Fig. 28.

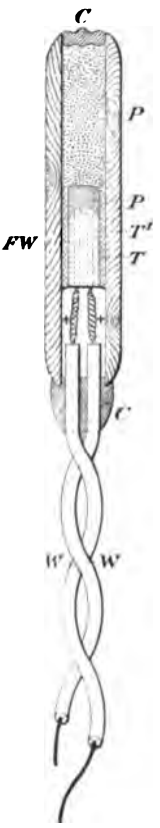


Fig. 31.

Fig. 30.

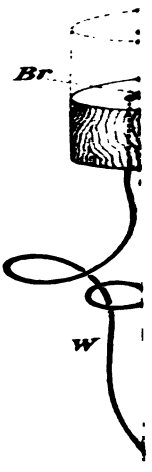


FIG.

FIG. 39.

FIG. 41.

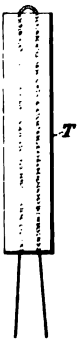


FIG. 38.

FIG. 40.

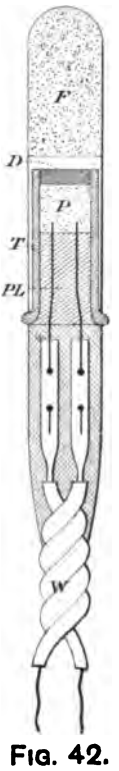


FIG. 42.

FIG. 43.

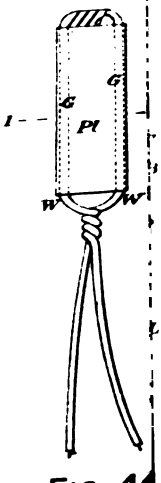


FIG. 44

FIG. 51.

FIG. 52.

FIG. 53.

Chesterfield

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE GRAND HOTEL, MANCHESTER, NOVEMBER 27TH, 1897.

MR. G. BLAKE WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Joint Meeting with the Chesterfield and Midland Counties Institution of Engineers at Sheffield were read and confirmed.

The following gentlemen were elected, having been previously nominated :—

MEMBERS :—

Mr. WILLIAM W. MILLINGTON, Mining Engineer, Hardman House, Hollinwood, Oldham.

Mr. WILLIAM RIGBY, Mining Engineer, King Street, Wigan.

Mr. JOHN CRIGHTON read the following paper on "Comparative Experiments on Models of a Capell, a Schiele, and a Crighton Excelsior Fan, under the same Conditions":—

COMPARATIVE EXPERIMENTS ON MODELS OF A CAPELL, A SCHIELE, AND A CRIGHTON EXCELSIOR FAN, UNDER THE SAME CONDITIONS.

By JOHN CRIGHTON.

The writer takes this opportunity of proving to the members the fallacy of the experiments made on a Capell and a Schiele fan at Shirland colliery in the beginning of 1890. The experiments were communicated in a paper by Mr. M. Deacon having the title of "Comparative Experiments upon a Capell and a Schiele Fan Working under Similar Conditions."* The writer contends that this title is erroneous as, the conditions not being equal, the experiments are misleading and likely to act prejudicially to the Schiele fan.

To prove his opinions, the writer has had made a model Capell fan 12½ inches in diameter and 5¼ inches wide (Figs. 3 and 4, Plate XXV.), exactly to the drawings shown in the *Transactions*,† but to the scale of 1 inch to 1 foot, and with the exception that there is a double inlet in place of a single inlet to the fan, the sole reason for doing this being to have both of these fans working under the same conditions. In any case, Mr. Capell will no doubt readily admit that the altered conditions will, if anything, add to the efficiency of his fan. This Capell fan is enclosed within a casing or volute chamber exactly to the curves shown in the drawing in the *Transactions*.

The model Schiele fan (Figs. 5 and 6, Plate XXV.) is 12½ inches in diameter, and is arranged so that it fits into the same casing, but is supplied with its own ordinary volute chamber. The width of this fan at its tip should have been 2½ inches, but when received from the tinsmith the diaphragm was found to run ⅜ inch out of truth, and the wings had to be reduced to 2⅛ inches wide, thus very considerably reducing the capacity of the fan for the delivery of air, the curved rings between which the disc revolved being left as they were, viz., to receive a disc 2½ inches broad.

The model Crighton excelsior fan (Figs. 1 and 2, Plate XXV.) is 12½ inches in diameter and 5¼ inches wide, and is arranged to run between the same sidewalls as the Capell fan.

* *Trans. Fed. Inst.*, vol. i., page 287. † *Ibid.*, Plate I., page 290.

TABLE I.—COMPARATIVE EXPERIMENTS UPON MODELS OF CAPELL, CRIGHTON AND SCHIELE FANS, EACH FAN BEING 12½ INCHES IN DIAMETER, AND THE DIAMETER OF THE FAN-INLET BEING 6⅞ INCHES.

No. of Experiment.	Type of Model Fan.	Revolutions per Minute of Fan.	Velocity of Air-current per Minute with 30 Added for Friction of Anemometer.	Area of Fan-inlet.	Volume of Air per Minute.	Water-gauge.		Horse-power in Air.	Electrical Energy.						Useful Effect.	Ratio of Efficiencies.
						Open.	Closed.*		Volts.	Ampéres.	Watts	Horse-power.	Friction of Motor.	Actual Power Required to Drive Fan.		
			Feet.	Square Feet.	Cubic Feet.	Inches.	Inches.									
1	Crighton Excelsior	1,595	4,475	—	—	1·2	—	—	—	—	—	—	—	—	—	—
2	,, ,,	1,590	4,540	—	—	1·2	—	—	—	—	—	—	—	—	—	—
3	,, ,,	1,600	4,520	—	—	1·2	—	—	—	—	—	—	—	—	—	—
	Mean results ...	1,595	4,512	0·258	1164·01	1·2	1·8	0·220	100	6·0	600	0·804	320	0·375	58·69	1·00
4	Capell	1,600	3,658	—	—	0·75	—	—	—	—	—	—	—	—	—	—
5	,, ...	1,597	4,051	—	—	0·75	—	—	—	—	—	—	—	—	—	—
6	,, ...	1,595	3,786	—	—	0·75	—	—	—	—	—	—	—	—	—	—
	Mean results ...	1,597	3,832	0·258	988·37	0·75	1·5	0·117	100	5·4	540	0·723	320	0·295	39·62	0·675
7	Schiele	1,597	4,024	—	—	0·85	—	—	—	—	—	—	—	—	—	—
8	,, ...	1,595	4,054	—	—	0·85	—	—	—	—	—	—	—	—	—	—
9	,, ...	1,597	4,927	—	—	0·90	—	—	—	—	—	—	—	—	—	—
	Mean results ...	1,596	4,335	0·258	1118·43	0·86	1·4	0·152	100	7·2	720	0·965	320	0·536	28·28	0·480

* Fan-inlet entirely closed.

T. H. WORDSWORTH.
H. INGOLD.
HARRY RHODES.

These model fans are driven by an electric motor of 1½ horsepower, the maximum speed of which is 1,600 revolutions per minute (*A*, Fig. 2, Plate XXV.). Each model fan can be coupled direct on to the spindle of the electric motor (the same coupling *B* being used in all cases), so that the speeds may be exactly the same in each experiment. A voltmeter and an ammeter, to register the amount of horsepower consumed, were also provided, and were read at the time of the experiments being made.

The anemometer is fitted with the ordinary stop arrangement, with the addition of a catch and simple reversing motion for bringing it back again to zero after the end of each experiment. This meter *C* (Fig. 1, Plate XXV.) will be used in every case in one fixed position, a slide being provided along which the arm is moved to fix it in its proper place.

The water-gauge *D* (Fig. 1, Plate XXV.) is fixed at the back of one of the inlet-boxes, and in a position where there will probably be no current of air; but in any case it will apply equally to all the experiments on the model fans. For closing up the air-inlet entirely, a thin board is placed over the end of the inlet-pipe.

From the experiments shown in Table I., it will be seen that the writer is right in his opinion respecting the results recorded in Mr. Deacon's paper. The model Schiele fan passed 130 cubic feet of air per minute more than the model Capell fan at 1 revolution per minute less and produced 0·11 inch more water-gauge, even with its disc 2⅛ inches wide in place of 2½ inches wide (as it was intended to be), the slipping of air due to this deficiency, and the wobbling of the fan, no doubt accounting to a great extent for the low useful effect registered.

The result for the Crighton excelsior fan speaks for itself.

The experiments were made in the presence of the members, and the various observations in Table I. were recorded by Messrs. T. H. Wordsworth, H. Ingold, and Harry Rhodes.

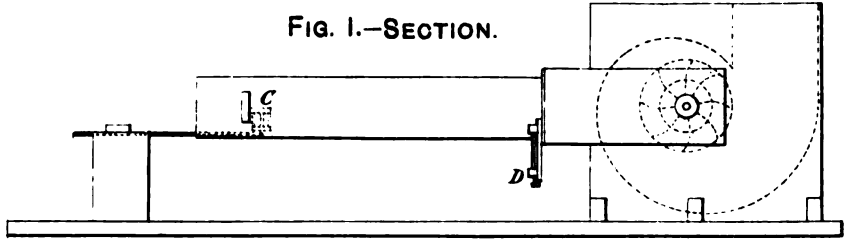
The PRESIDENT moved a hearty vote of thanks to Mr. Crighton for his paper and experiments upon model fans.

The proposal was agreed to.

The Federated Institution of Mining Engineers.
Transactions 1897-8

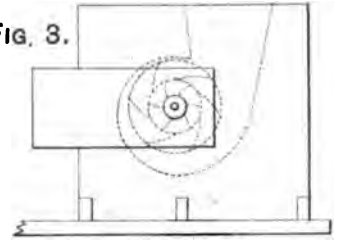
To illustrate M.r John Crighton's Paper on "Comparative Experiments on Models of Fans."

FIG. 1.—SECTION.



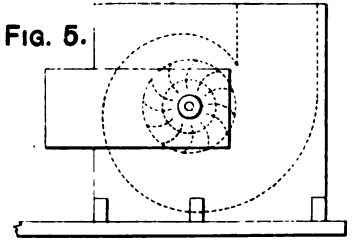
CRIGHTON EXCELSIOR FAN.

FIG. 3.



CAPELL FAN.

FIG. 5.



SCHIELE FAN.

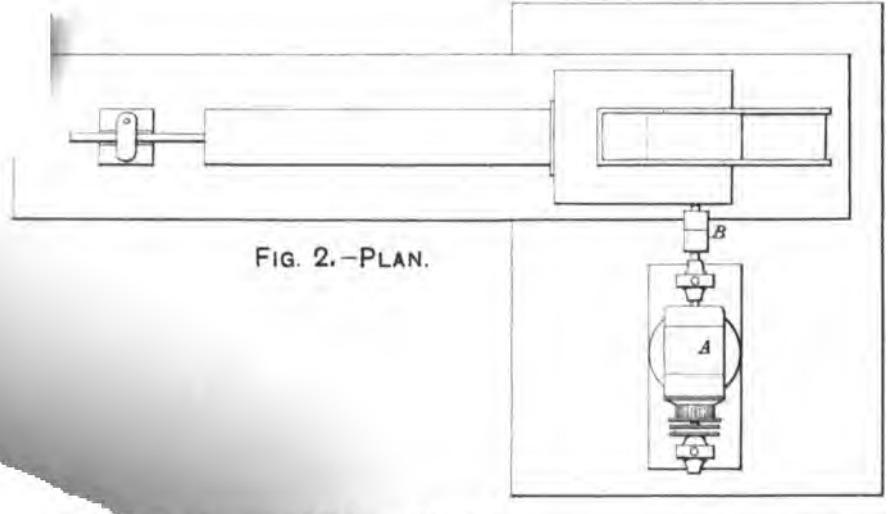


FIG. 2.—PLAN.

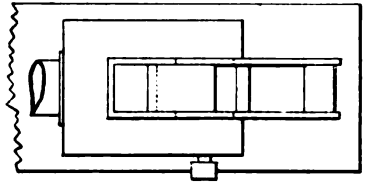


FIG. 4.

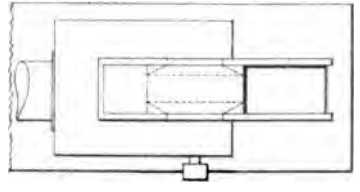


FIG. 6.

Scale, 2 Feet to 1 Inch.

...d Mining Civil & Mechanical Engineers,
...ransactions 1897-8

And.r Reid & Compy L.d Newcastle on Tyne

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,
FEBRUARY 9TH, 1898.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. WILLIAM GIBSON, 39, Park Road, Glasgow.
Mr. J. J. JONES, Great Eastern Colliery, Springs, Transvaal
Mr. DAVID PATERSON, Westburn Colliery, Newton.
Mr. CHARLES RUSSELL, Milnwood Colliery, Bellshill.

ASSOCIATE MEMBERS—

Mr. ANDREW F. HARGREAVES, Roslin Gunpowder Mills, Roslin.
Mr. ROBERT HUNTER, 72, Waterloo Street, Glasgow.
Mr. ROBERT RAMSAY, Chapel Colliery, Newmains.
Mr. DAVID D. WARREN, 72, Waterloo Street, Glasgow.

In closing the discussion on Mr. John A. Wauchope's paper on "The Gold-fields of the Hauraki District, New Zealand," the PRESIDENT proposed a hearty vote of thanks to the author, which was awarded.

DISCUSSION OF MR. WM. F. LANG'S PAPER ON "THE BROWN HYDRAULIC SYSTEM FOR UNDERGROUND PUMPING AND HAULAGE."*

Mr. JOHN LOVE (Loanhead) wrote that the Brown hydraulic system for underground pumping and haulage had now been working very satisfactorily under the charge of the writer for the last 3½ years. Mr. Lang states that "the pumps, which are of the wellknown bucket-and plunger type, to give a continuous flow of water, are 5 inches in diameter."† He should have stated that the bucket is 5 inches in diameter being double the area of the plunger, which is 3½ inches in diar

* *Trans. Fed. Inst.*, vol. xiv., page 47. † *Ibid.*, page 48.

The up-stroke of the bucket takes in water sufficient to supply both up-and-down strokes of the plunger; practically speaking, a continuous flow of water is put into the power-pipe with four plungers 3 inches in diameter. In the tests made of this pump, he (Mr. Love) obtained fully 60 per cent. of the indicated horse-power.

Mr. Martin asked what advantage a 4½ inches return-pipe gives with a 4 inches power-pipe. He (Mr. Love) agreed with the reply given by Mr. Lang; and, as to the slip in this class of pump, he might state that the pump had been working night and day for 3½ years, and the strokes of the pump aboveground are counted every day, and compared with the work done belowground with the result that, in the whole of that time, the difference is scarcely perceptible. Mr. Martin stated that the motion of the water in the power-pipes is not continuous, but his statement is incorrect, as the motion of the water in both the power-pipes and rising-main is continuous. The distributing-valve, referred to by Mr. Lang in his paper, is in his (Mr. Love's) opinion a great success, compared with any other valve for the same purpose that has come under his notice, as there is no throttling of the water when distributing the water to the four different rams. The water in the power-pipes and return-pipes when standing is equally balanced, consequently, the pump aboveground when started puts the column of water into motion with the additional power added to do the work required. Mr. Lang stated that the Loanhead engine was capable of supplying power-water at a pressure of 1,000 lbs. per square inch, and he had already given reasons for claiming that the Loanhead pump was suitable for forcing water against much higher heads than 990 feet. He (Mr. Love) agreed with Mr. Lang's statement, and he might add that when taking his tests and getting 800 lbs. pressure on the power-water, there was only 75 lbs. per square inch on the steam-piston, and by putting a boiler-pressure of 100 lbs. per square inch on the steam-piston he would get 1,000 lbs. per square inch on the power-water, which, as Mr. Lang stated, would force the water to much greater heads than 990 feet. As stated by Mr. Lang, in answer to Mr. Martin, the distributing-valve had no tendency to leave the valve-face, neither had it ever left it, save when taken off by hand.

There was one good point in his (Mr. Love's) opinion in favour of the Brown hydraulic pump over the Moore pump:—that the engine and pump aboveground having power-plungers smaller in diameter than the power-plungers belowground, the engine-pump runs at about 2½ times the speed of the pump below, acting similarly to a geared engine, the

stroke of the one having no connexion with the stroke of the other, but keeping always a continuous and steady pressure on the power-water which was always moving in one direction, and so allowing branches to be put on the power-pipes at any point where pumping or haulage is required. On the other hand, the Moore pump had larger power-plungers on the surface than those in the mine, to enable the full length of the stroke to be got. Even with a larger plunger at the top than at the bottom, it is not always the case that the whole length of stroke is obtained, unless the equalizing-valves are absolutely perfect.

Mr. Dixon had brought up a question of very great importance to him (Mr. Love), who was using the hydraulic system of haulage, and no doubt to many others, that is, the regulation of the system to varying loads. He (Mr. Love) had had this question before him ever since this system of haulage was introduced at Loanhead, as the quantity of water used was the same whether the load was light or heavy. In his (Mr. Love's) case, the motor was hauling out of a dook, 3,000 feet long. In the top half of that distance, the gradient is 1 in 12, and the bottom portion is flatter. The empty hutches can only take the dook-rope down to half the length of the dook; a tail-rope is then used, and the motor started to haul the hutches and dook-rope the other half of the distance, using the same quantity of water according to the distance travelled by the hutches, although little power was required. To save water, he (Mr. Love) intended putting a large pinion-wheel on the driving-shaft alongside of the small pinion, and a small pinion on the drum-shaft alongside of the large pinion. When the load is light, the large pinion will be put into position to act as the driving-wheel, causing the drum to revolve at a greater speed, while the motor-winch is going very slowly.

Mr. R. T. Moore (Glasgow) said that he had read Mr. Lang's paper with interest. He had also had an opportunity of inspecting the Brown hydraulic pump at Loanhead, where it appeared to be doing excellent work, and the officials who had experience of it spoke highly of it. The pump was a hydraulic-engine, worked by water-pressure, which was supplied by a pressure-pump driven by a steam-engine on the surface. As Mr. Lang said, there was nothing novel in the system. It was in every-day use at docks, and had been employed in mines. An installation on the same system had been designed and erected by Mr. Joseph Moore some 20 years ago, on the Comstock lode, to throw 2,000 gallons of water a minute to a vertical height of 1,600 feet, and a paper describing it was read before the Institution of Engineers and Shipbuilders* in Glasgow.

* *Trans.*, vol. xxv., page 177.

There could be no doubt that it was very suitable for its purpose. The trouble he had anticipated was that, with the usage to which pumps were subjected at a colliery, there would be difficulty in keeping the actuating-valves tight under the high pressures which it was desirable to employ. At Loanhead, however, he was informed that with Mr. Brown's distributing-valve there was no trouble, and this seemed to meet his difficulty. Mr. Lang's description of the valve was very good, but it was difficult to follow a description of that kind without a drawing.

He thought that it was a mistake to employ a rotary motion for pumping, as Mr. Brown did, and that this would be more and more felt when high pumping speeds were attempted. With a reciprocating pump—such as a Moore pump, or one driven by a direct-acting steam-engine—there was a pause at the end of each stroke; during this time the valves closed slowly, and on the return-stroke of the ram the pressure of water came against a valve which was completely closed. With a rotary engine there was no pause, and when the stroke was reversed the valve was slammed down on to its seat with the full pressure of water on top of it. This was largely the reason why valves lasted a much shorter time with rotary pumping-engines than with direct-acting ones. Many attempts had been made to get over this difficulty—notably the Riedler pump, where the pump-valves were worked by the engine, the valve being held close to the seat towards the end of the stroke, and closed instantly by a spring the moment the stroke was finished. Considerable pumping speeds had been attained by this system, but he, personally, preferred to have a pause at the end of the stroke to allow everything to come to rest before the new stroke was begun.

He quite agreed with Mr. Lang that it was feasible to throw water to great heights in one lift. The Loanhead pump which Mr. Lang described was throwing 990 feet. A Moore pump had been applied to throw 1,020 feet, and the Moore pump at Niddrie was throwing water 660 feet. There was no difficulty in throwing water, with a pump driven by hydraulic power, any height that could be thrown with any form of pump. It was only a question of making the power-cylinders of such a size, that with a working pressure of 1,000 lbs. per square inch they would work the pump against the head. While this was so, he doubted whether high lifts were economical. In his own practice—unless there was strong reason to the contrary—he thought it better to divide the head into lifts of 480 feet, and this was on account of the pumps—not the power part of the apparatus. With a lift of 960 feet, pump-valves were more difficult to keep than with one of 480 feet. The pump had to be

made twice as strong, and the lower 480 feet of rising main and power-pipes had to be made twice as strong. In first cost, there would be one-third more cost of power-pipes, and one-third to one-half more cost of rising main, to set against the saving in cost of having one pump, which had to be made double the strength of each of the two which were required for 480 feet lifts. In many cases, the first cost of the two 480 feet lifts was less than the cost of the single 960 feet one, and he was satisfied that the cost of maintenance was less. In most cases, too, there were feeders of water which could be caught at intermediate points and more economy got than if all the water were run down to the bottom.

In the paper and in the discussion, a good deal of importance had been attached to the application of the system to haulage. He thought that haulage was one of the things to which the application of hydraulic power was most unsuitable. Hydraulic power was only economical when it was working against an uniform load. When a steam-engine was working against a light load, the throttle-valve could be closed and less steam would be used, but with a hydraulic engine, the cylinder had to be filled with water at every stroke, no matter whether it was working against a heavy load or a light one. Experiments had shown that with hydraulic motors it took twice the power to start a load that it took to keep it going, and in a haulage plant, a margin had also to be allowed for varying gradients, heavy hutches, and many other things. He would not be far out if he said that the hydraulic motor would have to be made at least 2½ times stronger than was required for the average work that it had to do, and it would have to be kept doing this work all the time it was running, whether it was drawing one hutch or twenty.

Nothwithstanding Mr. Lang's result of 55 per cent. efficiency in pumping—which he had no doubt was correct—he did not think that hydraulic hauling-motors gave more than from 40 to 50 per cent. of the power of the water going into them, or about 30 per cent. of the power of the surface driving-engine. If this had to be divided by 2½ on account of the engine being too big for its work, the efficiency of the hauling-motor was reduced to 12 per cent., and better results than this could be obtained from compressed air or electricity. No doubt self-regulating engines, such as those which were at one time made by Messrs. Hastie, of Greenock—where the crank-pin was made movable so as to give a long stroke with a heavy load, and a short stroke with a light one might be tried, but none of these devices seemed to have worked well in practice. On the whole, he did not think that there was much to be gained by using hydraulic power for both pumping and haulage.

Some questions as to the Moore pump had been raised in the course of the discussion. While he was perhaps prejudiced, he thought that the Moore pump was simpler than the arrangement described, in having no working valves under high pressure either at the power-station on the surface or at the pump below, and this would probably account for the higher efficiency which was got from it. There was no difficulty in working several pumps from one set of power-pipes with the Moore pump. There had been three pumps working in this way, at one installation, and a haulage-motor could be worked as readily from the power-pipes as from the water-pressure system. There was no difficulty in overcoming the loss of stroke due to the compression of water for distances between the engine and pumps up to 1 mile, but beyond this distance, he had always held that it might be preferable to employ the continuous-pressure system. The cases, however, where power for pumping had to be conveyed more than 1 mile were rare—in Scottish collieries, at all events.

The PRESIDENT thought that Mr. Moore had put the members right, as there was an idea that they could not work branch force-pumps from the Moore pump. If they could do so, it would take away a considerable portion of the advantages claimed for this pump.

There being no further discussion, Mr. Lang was accorded a hearty vote of thanks.

DISCUSSION ON MR. ORSMAN'S PAPER ON "SOME DEFECTS IN GUNPOWDER AS A BLASTING AGENT"* AND MR. A. F. HARGREAVES' PAPER ON "HIGH-GRADE GUNPOWDER."†

Mr. F. J. ROWAN (Glasgow) said that he shared the feeling which was expressed at last meeting, to the extent of having the opinion that Mr. Orsman's communication was more fitted to find a place in the discussion on Mr. Hargreaves' paper than as forming a separate paper. Mr. Hargreaves contented himself with a defence of gunpowder and with arguments to establish the advantages of a quality of a higher grade than that of the ordinary blasting-powder, and it appeared to him that it would have been more suitable had Mr. Orsman similarly contented himself with setting forth the excellencies of roburite. He had, however, challenged a comparison between gunpowder and roburite as representing the nitrate-

* *Trans. Fed. Inst.*, vol. xiv., page 57. † *Ibid.*, vol. xiv., page 2.

of-ammonium class of explosives, and could not complain if attention were drawn to the drawbacks to the use of these. There are two grounds upon which the question of explosives must ultimately be settled :—first, that of safety ; and, secondly, that of cost.

I.—As regards safety, the experiments carried out by The North of England Institute of Mining and Mechanical Engineers' Explosives Committee, the Prussian Fire-damp Commission, the French Commission on the Use of Explosives, and the Westphalian Miners' Provident Society had proved that none of the so-called "safety-explosives" were flameless or absolutely certain not to cause ignition of fire-damp and coal-dust in the case, at any rate, of blown-out shots. The photographs of the flames actually produced by most of these explosives which had been published by Mr. Siersch* settled the question of flamelessness finally, and disposed of any doubts which might have existed on the subject from the experiments in the test-galleries. This being so, "permitted explosives" could claim no large margin of safety or superiority over gunpowder under the conditions of blown-out shots. Mr. Orsman, however, argued that danger from the ordinary use of blasting-powder, *i.e.*, even in successful shots, arises from the fact that solids as well as gases result from its decomposition, and that these solids must be projected at the temperature of explosion into the atmosphere of the mine. But here Mr. Orsman tried to claim too much. It was true that solid compounds of potassium, as well as gases, resulted from the combustion of gunpowder, but there was no proof of danger of ignition of gas or dust from any solid material other than portions of the carbon of the powder which were sometimes ejected in an incandescent state when a charge had been incompletely burned. The experiments and researches of Sir Frederick Abel and Captain Andrew Noble (whose name was sometimes confounded with that of the late Mr. Alfred Nobel) had shown that at the temperature and pressure of explosion the potassium compounds which were formed existed first of all in the liquid form, and that they were deposited as solids on cooling ; so that when they had become solid they had not the theoretical temperature produced by the explosion. Even if they had, there was no proof that they were then incandescent or capable of becoming so, or that such substances could ignite fire-damp or coal-dust. Mr. Orsman stated that they took $1\frac{3}{4}$ minutes to become solid.† Surely he did not wish us to believe that at $1\frac{3}{4}$ minutes after an explosion there was danger of ignition from these solids, or that it took all that time to consummate an explosion of gunpowder ? With solid carbon the case was,

* *Trans. Fed. Inst.*, vol. xi., page 2, and plates I. to VI. † *Ibid.*, page 57.

of course, quite different; but with the finer qualities of gunpowder the risk of incomplete combustion was reduced to a minimum, and, with improvements in methods of manufacture, there was no doubt that it might be wholly eliminated.

There was little doubt that the presence of carbon monoxide among the products of explosion constituted a serious drawback to the use of blasting-powder in mines. On this point, however, it seemed to him, on looking farther into the matter, that Mr. Hargreaves might easily have made out a better case for gunpowder than he did in his paper; for Messrs. Bunsen and Schischkoff found that the gases from sporting-powder, which contained a comparatively large proportion of nitre, showed only 3 per cent. of carbon monoxide, and among Capt. Noble's analyses* of the products of the decomposition of gunpowder of various brands there were three showing respectively 0·86 per cent., 1·36 per cent. and 2·47 per cent. of carbon monoxide, none of them having more than 0·06 per cent. of marsh gas or hydrogen in addition. These were very satisfactory facts for users of gunpowder, and they offered great encouragement towards further improvement of the material.

At present there seemed little doubt that, given nitrate-of-ammonium compounds fresh and unaltered in chemical composition and perfectly fired by complete detonation, they had on the score of non-combustible products a superior degree of safety to gunpowder. But, on the other hand, many of these compounds changed rapidly with age or exposure to the air, and as a consequence miss-fires were pretty wellknown with these explosives. These miss-fires introduced possibilities of danger from a different cause than combustible products, but not the less a serious one, and the fact that "safety-explosives" required the employment of risky detonators, itself suggested that should the use of these new blasting-agents become anything like so general as that of gunpowder in the past, a new class of accidents from the handling of these substances was likely to arise.† Indeed, Mr. Gerrard, one of H.M. inspectors of mines, has already said in public discussion of this question, that he "regarded the distribution of detonators generally to the colliers with dismay," no doubt on account of the disastrous results which he expected would follow.

The great tendency to deliquescence which these explosives possessed had made it necessary for the cartridges of some of them to be wrapped

* "Heat-action of Explosives." by Captain Andrew Noble, C.B., F.R.S., M.Inst.C.E., *Heat in its Applications: A Series of Lectures, delivered at The Institution of Civil Engineers*, 1883-84, page 201.

† *Trans. Fed. Inst.*, vol. xiv., page 165, contains an early comment on this subject.

up in paraffined paper covers, but these covers when left on the cartridges before firing, as they were pretty sure to be in actual use, introduced the very element of danger objected to in gunpowder, viz.:—the presence of carbonaceous material which might be projected in an incandescent state into the atmosphere of the mine.

From the point of view of safety, therefore, the permitted explosives have not everything in their favour; and

II.—On the score of cost they were hopelessly in the rear. The comparative trials carried out by members of this Institute at Auchinraith, Milnwood, Whistleberry, Lanemark, Newton and Hallside, and Bothwell Park collieries had shown that there was a decided increase of the cost of getting coal from Scottish coal-seams by their means. The figures showed from 95 to 210 per cent. increase in cost of the explosive used per ton of coal, accompanied by an increase in the proportion of small coal amounting to 6·9 per cent., 10·6 per cent., and in one case 25 per cent., equal to about 9 per cent. of the total produce. With regard to the use of safety-explosives in English collieries, Mr. Hall, H.M. inspector of mines at Liverpool, in a paper on "The Cost and Efficiency of Safety-explosives as compared with Gunpowder,"* asserted that "whatever the cost of blasting with gunpowder had been in a particular seam, that cost will be increased by one-half by changing to safety-explosives," and further that the proportions of round and small coal remained practically the same with both systems. Mr. Hall's figures were, however, subjected to a searching criticism in the discussion on his paper, and the experience of several prominent colliery-engineers and coal-masters proved that he had very considerably understated the difference in cost, and was wholly wrong as to the proportions of round and small coal.

Apart altogether from the regulation as to withdrawal of all the men from a pit before shot-firing, which would entail additional cost in coal-getting, and which had come in concurrently with those as to permitted explosives, there was a decided weight of opinion expressed against these explosives—on the ground of the increased cost of coal-getting which they involved. That was a matter which affected every user of fuel and extended in its influence as far as the limits of British industries. It was pointed out that the proportions of round and slack for safety-explosives mentioned by Mr. Hall were arrived at by the use of screens provided with bars less than half their former width apart, and that coal passed over $\frac{3}{8}$ inch bar-screens could not have the value of

* *Trans. Fed. Inst.*, vol. xiii., page 4.

that made over 1 inch screens. At two collieries under the charge of Mr. J. J. Prest (Stoke-upon-Trent), the production of slack was increased by the use of ammonite, the cost per ton for explosive being double what it was with blasting-powder. For the production of black-band ironstone, the cost of explosives was, with blasting-powder and fuze, 0·910d. per ton; with ammonite, detonators, etc., 1·706d. per ton, showing an increase of 0·796d. per ton. Mr. M. Deacon (Sheepbridge) showed that an increase of 5 to 6 per cent. of slack would entail a reduction in the average selling-price of coal of about 3d. per ton in many collieries, and if 1d. per ton extra for explosives were added this would make the loss overhead 3d. or 4d. per ton. Mr. J. H. Merivale, however, gave figures to prove that instead of 1d. additional, the cost of safety-explosives would be 2·19d., whilst Mr. J. A. Longden (Stanton) gave the following figures:—At the Stanton collieries, 180 shots are fired every day, 118 in coal and 62 in stone:—¾ lb. of blasting-powder was used for a shot in stone and ½ lb. for a shot in coal: 12 ounces of blasting-powder being equal to 5½ ounces of roburite. The blasting-powder required a fuze costing ½d., and the roburite-charge a detonator costing 2d., therefore the cost of each shot was as follows:—¾ lb. at 4d. per lb., and ½d. or 3½d. for each shot of blasting-powder in stone, and 2½d. for each shot in coal; 5½ ounces of roburite at 1s. per lb., and 2d. or 6d. for each shot of roburite in stone; 3⅔ ounces at 1s. per lb., and 2d. or 5d. for each roburite-shot in coal. This showed 70 per cent. increase of cost for stonework, and double the cost for coal. This opinion was still further emphasized by Prof. H. Louis and others, Mr. J. A. Longden pointing out that a loss of 1d. per ton meant £9,000 per annum in the case of a colliery turning out 2,000,000 tons per annum. More recently Mr. J. G. Weeks,* of the Bedlington collieries, stated that the extra cost of safety-explosives, the lessened proportion of round coal and the diminution of output per man per shift caused by their use, involved an increased cost of 6·5d. per ton, which on an annual output of 1,000,000 tons would cost a colliery company £27,083—"very much too costly an amount for an alleged theoretically beneficial result," as he remarked. The matter was therefore sufficiently serious to justify strenuous opposition to any measures which would make such an increased cost compulsory.

With reference to the improvement of gunpowder, he wished further to remark that the higher the pressure attending explosion the more complete was the combustion and the smaller was the quantity of undecom-

* *Trans. Fed. Inst.*, vol. xiii., page 584.

posed powder and of carbon monoxide in the residue; so that there was one point to aim at, either by means of larger charges or by chemical combinations. Again, it had been found that the addition of fatty matters, such as stearic acid ($C_{18}H_{36}O_2$) to gunpowder retarded combustion and acted in the same manner as increased pressure. In one case which had been recorded, a blank charge of 1·5 grammes composed of 100 parts of meal powder and 0·5 part stearic acid yielded on explosion the following results :—

	Per Cent.
Potassium sulphate, K_2SO_4	31·57
,, hyposulphite, $K_2S_2O_3$	22·25
,, carbonate, K_2CO_3	39·09
,, sulphide, K_2S	2·01
,, sulpho-cyanide, KCNS	0·74
Carbon, C	4·02
Sulphur, S	0·32

Apart from such methods of improving gunpowder, there was another direction in which escape was possible from the use of explosives which necessitated the employment of detonators, and that was by means of other compounds. Schultze white gunpowder was an example of these, and it yielded on combustion no bad residue and no smoke. Although not good for use in firearms, it was an excellent blasting-agent. Another powder, composed of 54 parts of ammonium picrate and 46 parts of nitre (potassium nitrate), which was described by Prof. Brugère in the *Comptes Rendus de l'Académie des Sciences*, showed that the whole of its carbon was burnt, whilst the volume of gases produced by explosion was about $2\frac{1}{2}$ times as great as that produced by an equal weight of gunpowder. This powder exploded at a temperature of 310° Cent., and without percussion. The reaction was thus expressed :—

$$C_6H_2(NO_2)_3ONH_4 + 2KNO_3 = 5CO_2 + 3N_2 + 3H_2 + K_2CO_3.$$

On account of the length of the discussion at the last meeting he was unable to take part in it, or do more than bring some of these chemical facts under the personal notice of Mr. Hargreaves. He had heard that since that date some improvements had been carried out in the manufacture of gunpowder, to which result he trusted the suggestions made at these meetings had contributed. It would be interesting if Mr. Hargreaves could give the members some account of what had been done and what was the composition and reaction of the improved mining powder.

Mr. Robt. McLaren (Glasgow) said that, while there was a tendency for each to laud the merits of his own and decry the merits of his oppo-

nents' explosive, what the members wanted were facts to go upon in order to help them to solve the problem as to which explosive would best suit their purpose. That gunpowder had its advantages was undeniable, probably for two reasons: its use was understood, and, so far as practical knowledge was concerned, nothing better had been brought forward with which to mine coal. Each class of explosives had its accidents while being used in connexion with blasting, of which the following was a list:—

Gunpowder class:

1. Ignition by spark while handling; a fruitful source of accident.
2. Forcing charge into a small hole, whereby the cartridge is burst and the contents are ignited by a spark.
3. Ignition of train of gunpowder in squib, instead of wick.
4. Shot hanging-fire, due to bad tape-fuze.

High-explosives class, grouped under two heads in list of "permitted explosives," as nitrate-of-ammonium and nitro-glycerine:

1. Careless handling of detonator.
2. Pressing frozen cartridges too hard: this refers to nitro-glycerine compounds.
3. Forcing charge into small hole.
4. Stemmer coming into contact with detonator in primer.
5. Shot hanging fire, due to bad tape-fuze; this will not occur if fired electrically.
6. Part of charge left in the hole unexploded.
7. Separation of the nitro-glycerine from the other compounds, when thawing in hot water instead of in a proper warming-pan.

No note had been taken in the above lists of the accidents due to coal-dust and gas, and as these more intimately concern the members, it was well to look at the facts in this connexion. The most disastrous explosions of coal-dust had undoubtedly been due to gunpowder, but, on the other hand, it had been officially declared that three cases of coal-dust explosions had occurred with high explosives. To get such an explosion two things were necessary, flame and pressure, and these must have been present in the cases referred to. No one questions that much flame was given off in an explosion of gunpowder, but some of those connected with high explosives would fain say that flame was unknown from an explosion of the latter class. Well, to begin, granted that the explosive itself gave off no flame, it had to be borne in mind that the detonator gave off flame, and unless the gases formed at the moment of

explosion were capable of extinguishing it, flame must be the result. Nevertheless, the danger from ignition of coal-dust or gas was very much lessened by using high explosives in preference to gunpowder.

In the discussion, exception had been taken to the number of deaths recorded by Mr. Hall, due to coal-dust explosions through gunpowder, especially in regard to the Blantyre and Udston explosions. Being one of the first to explore and examine the whole of the workings as soon as it was possible to do so after the accident at Udston colliery, he might be permitted to say that he was not satisfied that the initiation was due to an explosion of gunpowder; gas was found at several places, and its ignition might have been the first cause. At the request of the late Mr. R. Moore, he made several experiments with coal-dust collected at Blantyre and Udston collieries, and the result of these experiments went to show that the dust contained all the elements necessary to cause an explosion. Experiments were made on similar lines in England, and the results given before the Commission on Coal-dust. Had all the circumstances been known to Mr. H. Hall, he might not have included these accidents, but, on the whole, no blame could be attached to him for doing so.

Accidents with high explosives would decrease as the men got to know the explosives better, and it was very probable that with our extended knowledge of them they would be made to suit and do the work equally as well as gunpowder. Some time ago, experiments were tried with roburite at which he was present, and it was found in practice that by stemming lightly the explosive did the work as well as gunpowder could have done, which went to prove that our knowledge was at fault.

Mr. Hargreaves stated* that 90 per cent. of the shots fired in mines were charged with gunpowder, this proportion was rather under than over that figure in the eastern district of Scotland, when it was remembered that gunpowder was almost exclusively used in the shale-mines for blasting. It did not appear that any of the high explosives were absolutely safe, and the members of the Explosive Testing Committee in this connexion at page 9 of their report stated :—

> Moreover, as our experiments all tend to show that there is at present no such thing in existence as an absolutely safe explosive, that is to say, an explosive which in no conceivable circumstances could set fire to gas, and as we anticipate that the progress of science will give rise to great improvements, we think that notice should be given by the Secretary of State that he will revise the Permitted List from time to time, altering, if need be, the conditions of the tests.†

* *Trans. Fed. Inst.*, vol. xiv., page 3.

†*Report of the Departmental Committee appointed to inquire into the Testing of Explosives for use in Coal-mines*, 1897.

Mr. JAMES GILCHRIST (New Cumnock) said that he would describe a peculiar accident that occurred in a mine in Cumberland. When a magnetic appliance was used for firing a shot, the shot failed to go off, the battery wires were disconnected, the shot-firer lifted the wires and shook them, and the shot went off. He could hardly believe the man who told him so unlikely a story, but he had since seen a similar case reported in one of the mining newspapers. There may therefore be some unknown danger in electric shot-firing.

The PRESIDENT said that Mr. McLaren had been a little unfair to the different explosives, and should not have grouped permitted explosives of all kinds on the one side against gunpowder only on the other.

Mr. R. T. MOORE said he was afraid that the multitude of facts and figures on both sides went to justify the modern adage that there was nothing so fallacious as facts—except figures. He thought that a little too much was being made of the additional cost, larger proportion of dross, and greater danger of handling caused by the use of the permitted explosives. Experiments such as those made by the Scottish Institute—where workmen who had been in the habit of using gunpowder all their lives were put to use high explosives, which were new to them, for a fortnight—were highly misleading. Nothing else could be expected but that more dross would be made, and that the cost would be greater. But when men had become accustomed to their use he had no doubt that much better results would be got than in random experiments. He was lately at a colliery where a seam of coal, with an 18 inches rib of stone in the middle of it, was worked on the room-and-rance system, the rooms being 45 feet wide. The stone was blasted up from the bottom coal, after the top coal had been removed over the width of the room. To do this, three shots were put in the coal immediately below the stone—one at each side of the room and one in the middle. These shots were fired with gelignite, and the miners, who paid for the explosive, preferred it to powder. This had been going on for a couple of years without a single accident; so that it was needless to say that miners could not use high explosives with safety. There was no doubt, however, that in many cases the cost of working with them would be greater than with powder.

He thought that a much better way of preventing explosions would be to prohibit the use of explosives altogether, in mines where danger was likely to arise from their use. The Coal Mines Regulation Act gave H.M. inspectors of mines power to have an arbitration to decide whether the use of explosives in any mine was a dangerous practice, and he thought that was sufficient.

It must always be remembered that, although large explosions came prominently before the public, they did not by any means cause the greatest loss of life in collieries; and, while they were all anxious that there should be none of them, he was much against the additional cost which would be placed upon many collieries where the precautions prescribed by the Home Office circular—which were of doubtful utility in any case—were quite unneeded. Even putting it on the low basis of a pecuniary one, now that coal-masters were liable for damages for every accident, they might be relied on to adopt permitted explosives in those mines where the additional safety would pay for the increased cost caused by their use. Mining would always be a hazardous occupation, and they must take care that they were not adopting the heroic policy of stopping mining accidents by shutting up the mines.

The PRESIDENT said that Mr. Rowan had raised an interesting question as to new causes of accidents through the permitted explosives.

Mr. HARRIS said that he had never heard of them before, and was not prepared on the spur of the moment to meet Mr. Rowan's statements.

The PRESIDENT, in adjourning the discussion, said he did not know whether the paper and the discussion had altered their opinions very much, but they had at least obtained some information on the subject, and they had learned that it was not by any means clear that permitted explosives were safer than gunpowder. Mr. F. J. Rowan had spoken of the danger of detonators, which was a thing that they must remember especially. He agreed with Mr. Moore's remarks on the subject of accidents and the cost of new explosives, and expressed the opinion that they would ultimately be furnished with a high-grade gunpowder which would be as largely used as the permitted explosives.

Mr. J. BARROWMAN (Secretary) read the following paper on "Mining Mortality":—

MINING MORTALITY.

By JAMES BARROWMAN, Mining Engineer.

In the writer's paper on "The Health Conditions of Coal-mining"* attention was called to the fact that the statistics available for making a comparison between the mortality of miners and that of persons engaged in other occupations were 15 years old.

Within the last few months the Registrar-general for England has issued a report for England and Wales,† based on the census of 1891, and bringing the information ten years further down. For the first time the Registrar-general for Scotland has included tables of comparative mortality in his report‡ based on the same census. It is proposed to set forth in this paper the results of these reports, in so far as they give us information relative to the comparative mortality of those engaged in the coal-mining industry. Dr. John Tatham, by whom the figures for England and Wales have been tabulated, is alive to the importance of the subject, and he has (in this last decennial report) added considerably to the information contained in the previous one. The report of Dr. R. J. Blair-Cunynghame for Scotland is made up on similar lines to that for England and Wales of Dr. Tatham's predecessor, Dr. Ogle, and on that account the two reports now to be considered are not in all respects comparable. It may therefore, on the whole, be best to deal with each separately.

England and Wales.

Judging from the improvements that have taken place in the conditions and methods of coal-mining, we should expect these to be reflected in the vital statistics in a lower comparative death-rate, in each succeeding report, whether from accident or from natural causes. We shall compare the last two decennial reports and see to what extent the figures answer these expectations.

With reference to accidents, Table I. shows the number of deaths

* *Trans. Fed. Inst.*, vol. xi., page 240.

† *Supplement to the Fifty-fifth Annual Report of the Registrar-general of Births, Deaths, and Marriages in England*, part ii.

‡ *Supplement to the Thirty-eighth Detailed Annual Report of the Registrar-general of Births, Deaths, and Marriages for Scotland.*

from various causes at eight different groups of ages in the ten years, 1871-80, while Table II. gives similar particulars for the next ten years, 1881-90, indicating 807 fewer fatal accidents in the latter period.

TABLE I. (ENGLAND AND WALES).—DEATHS FROM ACCIDENTS IN COAL-MINES, 1871-80.

Fatal Accidents caused by	Years of Age.								All Ages.	Per 1,000 Accidental Deaths.
	Under 15.	15-20.	20-25.	25-35.	35-45.	45-55.	55-65.	65 and upwards.		
Falls of roof and sides	291	605	688	1,120	871	667	344	102	4,688	485
Falls in shafts ...	53	83	91	211	152	100	67	27	784	81
Machinery, boiler-explosions ...	23	31	13	23	21	16	9	4	140	14
Waggons, tubs ...	413	307	120	151	117	114	85	43	1,350	139
Drowning	8	13	11	28	13	14	3	2	92	10
Blasting	4	15	27	66	41	15	10	2	180	19
Fire-damp	128	331	336	606	358	221	82	22	2,084	215
Choke-damp ...	19	50	45	88	49	29	11	3	294	30
Otherwise	13	13	6	7	16	2	6	3	66	7
Totals	952	1,448	1,337	2,300	1,638	1,178	617	208	9,678	1,000

TABLE II. (ENGLAND AND WALES).—DEATHS FROM ACCIDENTS IN COAL-MINES, 1881-90.

Fatal Accidents caused by	Years of Age.								All Ages.	Per 1,000 Accidental Deaths.
	Under 15.	15-20.	20-25.	25-35.	35-45.	45-55.	55-65.	65 and Upwards.		
Falls of roof and sides	200	492	511	1,034	957	697	403	97	4,391	496
Falls in shafts ...	39	65	53	94	96	88	36	17	488	55
Machinery, boiler-explosions ...	28	30	11	19	23	19	7	6	143	16
Waggons, tubs ...	318	412	150	160	150	141	114	63	1,508	170
Drowning	6	6	7	14	7	8	8	1	57	6
Blasting	1	15	25	67	51	34	13	2	208	23
Fire-damp	81	205	205	357	248	163	60	18	1,337	151
Choke-damp ...	18	51	38	70	54	32	29	9	301	34
Otherwise	39	90	42	74	63	63	48	19	438	49
Totals	730	1,366	1,042	1,889	1,649	1,245	718	232	8,871	1,000

In 1881, the coal-miners in England and Wales numbered 355,363. In 1891, the number was 482,525. When this large increase of miners is taken into account the decrease in the number of deaths from accident, regarded as a whole, is the more marked. But in looking at the causes of death separately it will be seen that the decrease does not h
them all. While the deaths per 1,000 in shafts and from
a gratifying decrease, those from falls are increased in

and there is a striking increase in deaths from waggons and tubs. This last increase appears to be due to the more extensive use of mechanical haulage in the later period, and one cannot peruse the annual reports of H.M. inspectors of mines without coming to the conclusion that many of these accidents are the result of recklessness or disobedience, and are largely preventable. This, of course, is true also of accidents from falls, which continue to be notoriously numerous.

The general improvement is set forth in another form in Table III., which shows the mortality of colliers from accidents per 1,000 living, in groups of ages during the two periods referred to. The decrease is most marked in the case of the younger men.

TABLE III. (ENGLAND AND WALES).—FATAL ACCIDENTS PER 1,000 PERSONS LIVING.

Period.	Under 15 Years.	15-20.	20-25.	25-45.	45-65.	65 and upwards.
1871-80 ...	3·7	2·6	2·6	3·0	3·6	3·1
1881-90 ...	2·7	1·7	1·4	1·9	2·8	2·9

In the compilation of the tables for both of the decennial periods, six different mining districts are distinguished and the particulars given for each separately. In Table IV., these districts are indicated, with the total mortality in each, distinguishing that due to disease and to accident respectively. Confining our observations still to a comparison of the accidents in the two periods, it is gratifying to notice that the decrease which we have seen in the industry as a whole holds good also in the several districts, although in varying degrees, with the exception of the district of Monmouthshire and South Wales, which does not show any improvement. There is a striking difference in the case of Durham and Northumberland which suggests the probability of some error in the figures for the earlier period. The unfavourable position of Monmouthshire and South Wales would appear to point to more dangerous conditions of working or less strict discipline. It may be appropriate to quote the following from the report for the year 1896 of Mr. Robson, H.M. inspector of mines for South Wales :—*

> I have from time to time in my reports referred to a want of discipline in many of the South Wales mines, and it still seems to me that this is at the root of much of the excess in the accident and death-rates, as compared with most of the other inspection districts.

It is not to be forgotten, that the occurrence of a great explosion in any district affects the death-rate temporarily in that district in a material degree. The Llanerch explosion of 1890 contributes to the high percentage of accidents in the Monmouthshire and South Wales division.

* Page 18.

TABLE IV. (ENGLAND AND WALES).—TOTAL MORTALITY IN COAL-MINES FOR THE TWO PERIODS, 1871-80 AND 1881-90.

Districts.	Total Mortality		Disease.		Accident.		Accident Percentage.	
	1871-80.	1881-90.	1871-80.	1881-90.	1871-80.	1881-90.	1871-80.	1881-90.
Monmouthshire and South Wales	1,081	1,145	852	902	229	243	21	21
Lancashire...	929	1,069	731	914	198	155	21	14
Staffordshire	929	952	757	817	172	135	19	14
West Riding of Yorkshire	772	912	611	798	161	114	21	12
Durham and Northumberland	973	774	924	678	49	96	5	12
Derbyshire and Nottinghamshire	734	727	571	638	163	89	22	12

TABLE V. (ENGLAND AND WALES).—COMPARATIVE MORTALITY OF MALES FROM 25 TO 65 YEARS OF AGE, ENGAGED IN DIFFERENT OCCUPATIONS.

Occupations.	1890-92.	1880-82.	1860, 61, 71.
All males	1,000	942	960
Occupied males	947	910	—
Clergyman	547	524	605
Physician	957	1,058	1,073
Commercial traveller	926	893	1,106
Farmer	591	595	673
Gardener	568	564	642
Fisherman	843	752	786
Publican	1,676	1,435	1,444
Grocer	664	726	744
Draper	984	833	1,132
Printer	1,048	1,009	1,144
Tailor	999	990	1,043
Tool, scissors and file-maker	1,398	1,198	1,169
Blacksmith	909	916	930
Mason	1,002	913	1,033
Joiner	779	772	831
Plumber	1,091	1,132	1,234
Potter, earthenware manufacturer ...	1,639	1,638	1,390
Coal-miner, Durham and Northumberland	753	822	919
Do. Lancashire	1,026	874	—
Do. West Riding Yorkshire ...	849	726	—
Do. Derbyshire and Nottinghamshire	693	691	—
Do. Staffordshire	930	874	1,099
Do. Monmouthshire and South Wales	1,102	1,017	1,218
Ironstone-miner	747	785	—
Tin-miner	1,405	1,730	1,363
Quarryman	1,164	1,057	1,043

Turning now to the mortality of miners from all causes, we have in Table V. the mortality from 25 to 65 years of age of miners in the several districts, and of males in some other occupations for the three periods 1860, 1861, 1871, 1880-82, and 1890-92.

Table VI. (England and Wales).

Comparative Mortality of Males, 25 to 65 Years of Age, in Different Occupations, from All Causes and from Several Causes.

Occupations.	All causes.	Influenza.	Alcoholism.	Rheumatic Fever	Gout.	Cancer.	Phthisis.	Diabetes.	Nervous System.	Disease of Heart.	Aneurism.	Circulatory System.	Bronchitis.	Pneumonia.	Pleurisy	Respiratory System.	Hernia.	Disease of Liver.	Digestive System.	Bright's Disease	Urinary System.	Plumbism.	Accident.	Suicide.	All other causes
Unoccupied males	2,215	56	23	2	3	96	448	10	630	37	12	191	84	135	24	51	4	53	39	35	47	0	81	28	126
File-maker	1,810	40	4	0	4	39	402	12	212	41	9	154	188	197	4	34	0	36	36	82	22	75	39	31	149
Lead-worker	1,783	32	0	0	0	27	148	0	232	40	13	219	152	187	0	58	0	80	67	85	76	211	45	13	98
Earthenware-manufacturer ...	1,706	42	9	8	1	35	333	9	123	43	6	178	376	135	8	149	3	32	31	45	18	17	20	16	69
Hawker	1,652	21	36	6	3	45	443	4	139	32	11	179	192	170	15	26	2	29	25	47	23	0	64	14	126
Publican	1,642	48	92	19	12	53	259	19	160	30	6	157	83	158	10	36	4	201	45	62	28	0	46	32	82
Tin-miner	1,409	12	4	4	0	50	508	8	99	20	9	66	144	107	22	104	9	28	13	29	16	0	48	0	109
Manufacturing chemist	1,392	56	7	7	0	54	162	7	98	47	3	118	249	204	23	26	5	23	40	26	26	1	98	13	99
Lead-miner	1,310	44	5	5	0	48	380	15	62	18	8	116	123	127	5	70	0	34	55	33	8	5	43	5	101
Musician	1,214	32	29	6	9	46	322	8	111	43	8	140	79	92	0	23	0	38	36	33	25	0	34	23	71
Quarryman	1,176	27	8	9	1	58	269	3	75	29	4	104	123	146	13	25	2	15	25	17	12	0	120	11	80
Coal-miner, Monmouthshire and South Wales	1,145	50	7	10	0	26	107	2	68	25	3	104	133	164	4	44	1	16	29	27	14	1	243	5	62
Plumber	1,120	29	13	9	10	53	217	6	131	31	9	102	96	95	7	26	3	22	28	63	21	19	52	16	62
Printer	1,096	32	10	10	4	48	326	7	98	26	7	100	102	82	9	21	2	30	33	35	17	3	19	17	58
Butcher	1,096	38	35	11	6	57	195	13	105	28	5	124	79	102	7	21	3	56	28	35	13	0	39	23	73
Law-clerk	1,070	35	22	6	8	62	272	8	123	10	2	89	66	86	5	26	0	34	35	59	33	0	33	12	44
Engineer and boiler-maker ...	1,070	27	10	9	3	47	195	7	102	28	8	112	99	141	7	23	4	31	29	33	18	0	54	9	74
Coal-miner, Lancashire	1,069	27	5	8	1	36	102	4	70	17	1	96	172	187	12	18	3	17	22	17	13	0	155	13	73
Draper	1,014	44	14	11	0	49	260	12	102	27	3	105	58	92	5	26	0	33	29	26	10	0	19	15	74
Mason	1,001	32	10	6	2	45	225	7	83	25	7	98	108	111	6	26	2	23	20	25	12	0	54	10	63
All males	1,000	34	13	7	2	47	192	7	102	24	6	102	88	107	7	22	3	29	26	28	16	1	56	15	66
Wool-manufacturer	991	29	3	13	1	49	191	7	100	22	3	106	104	121	10	21	2	21	40	32	13	3	21	12	67

Physician	966	51	14	3	8	43	105	22	122	28	6	96	12	93	7	13	0	60	49	56	23	0	37	41	77
Commercial traveller	961	26	23	6	3	63	174	13	89	25	7	113	59	91	6	21	2	47	26	37	16	0	46	15	53
Occupied males	953	33	13	7	2	44	185	7	82	23	6	97	88	105	7	21	3	27	25	27	14	1	56	14	66
Coal-miner, Staffordshire ...	952	35	2	5	1	37	83	7	65	21	2	107	177	110	8	24	1	8	19	22	14	0	135	6	63
Coal-miner, all districts	925	33	4	7	0	36	97	4	67	23	3	94	114	122	7	26	3	17	33	18	12	0	141	9	65
Baker	920	30	11	9	1	45	185	10	69	27	7	96	95	81	5	26	4	39	23	31	18	0	25	19	64
Shoemaker...	920	28	9	3	2	50	256	8	81	23	5	93	83	75	5	18	4	20	22	27	13	0	21	13	61
Clerk	915	31	14	9	4	40	218	12	98	25	5	85	60	81	9	22	1	26	26	32	16	0	21	21	59
Blacksmith	914	31	10	8	2	45	159	5	85	26	7	103	89	114	8	22	2	26	26	27	13	0	33	13	60
Coal-miner, Yorkshire, West Riding	912	26	4	6	0	32	123	5	52	22	3	89	120	143	6	19	1	16	21	16	7	0	114	14	73
Fisherman...	845	22	3	5	0	46	114	4	86	44	9	75	42	53	4	24	1	24	32	18	10	0	148	12	69
Railway-guard, porter, pointsman	825	32	5	6	2	43	147	5	66	21	5	74	61	67	6	22	0	18	18	23	10	0	137	8	49
Barrister	821	45	12	8	4	60	116	28	104	27	3	88	17	55	1	16	1	55	20	38	10	0	22	18	64
Railway engine-driver	810	41	2	7	1	46	76	14	114	37	4	98	61	74	16	15	5	20	26	21	13	0	79	3	47
Carpenter	783	26	8	9	2	44	172	8	71	19	4	83	59	75	5	15	3	21	21	23	11	0	39	12	53
Artist, sculptor	778	31	11	7	4	42	146	17	92	13	8	75	47	61	5	20	6	39	27	29	17	2	13	13	53
Coal-miner, Durham and Northumberland	774	23	5	6	0	40	94	4	74	22	5	98	50	73	8	25	4	23	25	15	12	0	96	8	64
Ironstone-miner	774	53	4	5	0	39	90	4	62	16	4	64	76	103	2	23	2	20	17	15	16	0	86	13	60
Domestic servant...	757	28	17	5	2	39	186	13	73	22	6	62	41	60	7	9	1	29	22	28	14	0	25	25	43
Brick-maker	741	24	8	5	0	45	84	5	79	21	4	80	80	102	4	15	4	17	23	23	9	0	37	11	61
Coal-miner, Derbyshire and Nottinghamshire	727	41	2	8	0	45	69	3	66	28	5	80	76	66	1	16	3	18	12	8	12	0	89	12	67
Grocer	664	24	8	9	1	34	131	10	66	17	4	73	47	56	5	13	3	26	23	26	14	0	16	12	46
Farm-labourer	632	37	4	5	1	36	115	5	53	16	3	70	46	66	4	13	3	13	19	12	9	0	42	8	52
Schoolmaster	604	26	8	10	2	39	111	8	71	30	5	67	22	43	3	10	3	21	25	25	8	0	8	15	44
Farmer	563	38	6	6	1	36	79	10	51	15	0	62	25	50	4	11	2	26	25	18	11	0	30	14	43
Gardener	553	27	4	7	1	36	112	4	47	14	3	60	41	47	4	13	0	17	18	16	10	0	22	10	40
Clergyman...	533	36	2	11	3	35	67	17	69	16	2	64	11	45	5	8	0	18	26	27	12	0	9	7	43

It is disappointing to observe that the mortality of miners in the last period is on the whole higher than in the period preceding; but when we compare the figures with the corresponding figures in regard to other occupations we find that there is a difference in the same direction, more or less, all through, largely due, it is believed, to the effects of the influenza epidemic in the last three years of the latest period.

Table V. does not show in their true relation the rates of mortality in different occupations, but is substantially correct as regards comparisons of mortality at the three different periods in the same occupation.

Comparing mining mortality with that of other industries, we have the true relation of the different occupations to each other brought out by Table VI., which shows the comparative mortality of males from 25 to 65 years of age in certain industries for the years 1890-1-2 from all causes, and also from several selected causes. The occupations are arranged in the order of mortality from all causes, beginning at the highest, the figure for all males being 1,000.

As compared with other occupations, that of the coal-miner holds a middle place in mortality from all causes, two of the districts being above and four below the standard of all males. The average of the six districts is 925, while occupied males are 953.

Arranging the different occupations separately, according to the mortality from the various causes given on Table VI., their relations are altered materially. We naturally turn to accidents as being an outstanding cause of death to miners, and it has to be sorrowfully admitted that the coal-miner stands high in the comparative mortality list as regards accidents; indeed the coal-mining industry of Monmouthshire and South Wales tops the list of all the industries of England and Wales as the most fruitful of accident. Table VII. shows this, and sets forth the comparative mortality in this and a few of the other industries most liable to accident.

But as regards disease, there is no one in which the coal-miner ranks outstandingly high. It was noticed in the paper already referred to that the death-rate among coal-miners from phthisis was exceptionally low, and Table VI. bears this out. Owing to the extremes of heat and cold to which miners are exposed, and the dusty atmosphere in which many of them have to work, diseases of the respiratory system are common. These, next to accident, have the highest place in the death-rate of miners. Comparing these with those of other occupations in which dust or changes of temperature may be held to have a decided influence, we have the order shown in Table VIII., the coal-miner occupying a distinctly favourable place in the list.

TABLE VII. (ENGLAND AND WALES).—COMPARATIVE MORTALITY FROM ACCIDENT OF CERTAIN OCCUPATIONS.

Occupations.	Mortality Figure.	Occupations.	Mortality Figure.
Coal-miner, Monmouthshire and South Wales	243	Stone, slate-quarryman	120
Bargeman	223	Coal-miner, West Riding Yorkshire	114
Seaman	202	Manufacturing chemist	98
Dock-labourer	162	Coal-miner, Durham and Northumberland	96
Coal-miner, Lancashire	155	Coal-miner, Derbyshire and Nottinghamshire	89
Fisherman	148	Ironstone-miner	86
Coal-heaver	144	Railway engine-driver	79
Coal-miner, all	141	General labourer	73
Railway road-labourer	141	Boiler-maker	64
Railway-guard, porter, etc.	137	All occupied males	56
Coal-miner, Staffordshire	135		
Slater	133		
Carman	128		

TABLE VIII. (ENGLAND AND WALES).—COMPARATIVE MORTALITY FROM DISEASES OF THE RESPIRATORY SYSTEM.

Occupations.	Mortality Figure.	Occupations.	Mortality Figure.
Earthenware-manufacturer	668	Wood-turner	276
Cutler	518	Brass-worker	273
Glass-manufacturer	445	Coal-miner	269
File-maker	423	Wool-manufacturer	256
Lead-worker	397	Bricklayer, mason	251
Tin-miner	377	Blacksmith	233
Zinc-worker	347	Baker	207
Cotton-manufacturer	338	Ironstone-miner	204
Stone-quarryman	307	Carpenter	154
Chimney-sweep	291	Agriculturist	115

SCOTLAND.

The coal-miners of Scotland have not been divided into districts, but are dealt with as a whole, and the shale-miners have been classed along with them.

As already indicated, a comparison cannot be made between the last and former reports in the matter of comparative mortality, as the former reports do not give the necessary particulars. Our examination of the tables, therefore, will be confined to what they tell us of the duration of life of the miner as compared with men in other occupations at the date stated in the last report.

Table IX. shows the comparative mortality of males between 25 and 65 years of age in several occupations from certain of the commonest diseases and accidents arranged in the order of mortality from all causes, the mean for all males being 1,000.

TABLE IX. (SCOTLAND).—COMPARATIVE MORTALITY OF MALES BETWEEN 25 AND 65 IN SELECTED OCCUPATIONS FROM CERTAIN CAUSES IN 1890-1-2.

Occupations.	All Causes.	Diseases of Nervous System.	Diseases of Circulatory System.	Diseases of Respiratory System other than Bronchitis and Pneumonia.	Bronchitis.	Pneumonia.	Diseases of Digestive System other than Liver Diseases.	All Liver Diseases.	Intemperance.	Diseases of Urinary System.	Cancer.	Phthisis.	Accident.	All Other Causes.
Publican	2,308	450	225	73	79	124	84	248	169	135	118	315	73	215
Hawker	1,839	117	336	103	220	172	48	14	34	55	62	274	144	260
Dyer, bleacher ..	1,775	203	312	48	196	176	68	14	14	88	68	413	33	142
Ironstone-miner ..	1,664	73	220	122	392	147	61	24	0	49	49	269	86	172
Mason	1,441	104	137	48	159	146	36	20	11	55	60	432	87	146
Dock-labourer ..	1,385	86	157	43	126	220	55	0	20	43	70	177	239	149
Cabman	1,271	155	134	34	87	144	24	26	26	71	34	256	115	165
General labourer ..	1,218	141	145	48	189	137	44	16	14	41	49	180	95	169
Earthenware-manufacturer	1,213	106	106	35	220	158	26	44	9	26	26	272	35	150
Shoemaker	1,201	164	145	38	129	80	41	37	15	64	65	217	34	172
Law-clerk	1,176	97	64	48	64	81	16	16	32	64	32	403	16	213
Carter, vanman ..	1,157	93	129	55	115	129	59	29	6	59	66	144	140	133
Painter, glazier ..	1,116	161	168	43	72	86	43	20	3	82	36	221	89	92
Physician	1,109	121	147	35	17	113	69	17	35	130	26	139	43	217
Butcher	1,098	147	138	31	54	94	54	31	36	58	54	232	31	138
Tailor	1,091	99	125	38	94	75	53	29	19	65	39	308	31	116
Jute-manufacturer ..	1,091	140	157	33	165	124	50	17	0	17	33	215	25	115
Slater	1,053	120	138	30	84	90	18	18	24	54	78	133	169	97
Commercial clerk ..	1,005	119	93	32	32	75	41	24	20	59	39	307	26	138
Baker	1,000	102	133	24	66	86	49	22	29	80	42	203	49	115
All males	1,000	114	123	35	90	94	45	20	12	45	47	168	79	128
Printer	988	119	136	48	61	40	57	4	9	53	22	303	35	101
Coal- and shale-miner	973	72	114	35	195	70	31	15	5	37	39	100	149	111
Commercial traveller	964	134	79	37	46	70	56	46	9	23	46	223	65	130
Cabinet-maker ..	958	129	108	33	87	95	41	25	4	17	58	228	17	116
Blacksmith	950	107	131	30	81	119	53	9	10	43	49	159	43	116
Plumber .. .	908	111	116	23	41	58	41	23	6	47	47	250	75	70
Grocer	907	106	115	24	44	89	60	40	18	66	51	171	22	111
Solicitor	901	165	94	8	23	102	39	63	8	31	71	63	31	203
Quarryman	889	59	73	30	79	69	50	18	7	40	46	208	106	109
Draper	872	88	96	19	38	50	31	28	8	46	35	334	19	85
Joiner	848	89	91	27	40	61	51	14	3	43	44	186	58	141
Railway-porter ..	818	68	108	27	37	78	10	7	0	34	44	122	186	97
Cotton-manufacturer	783	122	90	33	78	65	16	33	16	57	41	122	25	90
Fisherman	770	62	57	21	26	46	38	11	3	25	32	142	169	138
Schoolmaster	706	149	92	18	26	44	44	9	9	44	13	162	18	78
Gardener	649	85	89	12	43	62	37	13	5	41	53	82	48	79
Clergyman	581	123	66	18	26	35	57	9	0	57	22	57	22	89
Agricultural labourer	532	56	51	17	37	61	39	6	0	23	34	64	43	101
Farmer	529	50	66	12	17	47	36	17	3	29	49	69	30	104
Railway engine-driver	481	48	59	11	27	37	16	0	0	16	0	74	150	43

The figure for the coal- and shale-miner is 973, nearly as favourable (compared with all males) as that for the coal-miner in England and Wales; but the ironstone-miner takes an entirely different position, being near the top of the list on Table IX. and near the bottom on Table VI. The very different conditions of working in the two countries are no doubt the cause of this wide divergence. The ironstone-workings of England are chiefly in the Cumberland hæmatite, while those of Scotland are in thin stratified seams.

In the matter of accident, the coal-miner in Scotland occupies a somewhat similar relative position to other occupations that the coal-miner in England and Wales does. This is shown by Table X.

TABLE X. (SCOTLAND).—COMPARATIVE MORTALITY FROM ACCIDENT IN CERTAIN OCCUPATIONS.

Dock-labourer	239	Coal- and shale-miner	149
Railway-porter and servant	186	Hawker	144
Slater	169	Carter	140
Fisherman	169	Ironstone-miner	86
Railway engine-driver	150	All males	79

TABLE XI. (SCOTLAND).—COMPARATIVE MORTALITY FROM PHTHISIS IN CERTAIN OCCUPATIONS.

Hairdresser	450	Cabman	256
Mason	432	Plumber	250
Dyer, bleacher	413	Butcher	232
Law-clerk	403	Linen-manufacturer	225
Watch and clock-maker	376	Shoemaker	217
Draper	334	Stone-quarryman	208
Brass-manufacturer	320	All males	168
Publican	315	Coal- and shale-miner	100
Commercial clerk	307	Farmer	69
Earthenware-manufacturer	272	Gardener	64
Ironstone-miner	269		

TABLE XII. (SCOTLAND). COMPARATIVE MORTALITY FROM DISEASES OF THE RESPIRATORY SYSTEM IN CERTAIN OCCUPATIONS.

Ironstone-miner	661	Linen-manufacturer	307
Hawker	495	Coal- and shale-miner	300
Dyer, bleacher	420	Carter	299
Earthenware-manufacturer	413	Plasterer	282
Mason	353	All males	249
Boilermaker	340	Clergyman	79
Hairdresser	333		

What has already been stated as to the comparative immunity of the coal-miner from phthisis in England is true also for Scotland, as set forth in Table XI., which shows the coal- and shale-miner in the low place of 100, as against 450 for the highest and 64 for the lowest.

The ironstone-miner is outstandingly high in mortality from diseases of the respiratory system, while the coal-miner holds a medium place, as shown on Table XII.

The conclusion that these, the latest reports of the Registrars-general lead to, therefore, is, that while the coal-miner is liable to accident in a greater degree than most other workmen, the occupation is a particularly healthy one; and that as regards mortality from all causes, even including accident, the miner is more favourably situated than the bulk of his fellow men.

Mr. F. J. ROWAN asked whether in the reports there was any reference made to workers in whitelead, and whether the rate of mortality as regarded those engaged in the manufacture of gunpowder and explosives was included.

The SECRETARY believed that "lead-worker" meant a worker in a whitelead work, and the rate of mortality was high. Workers in explosive-manufactories were not shown separately in the tables.

The further discussion of the paper was adjourned.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL, LONDON, JUNE 3RD, 1897.

MR. LINDSAY WOOD, PRESIDENT, IN THE CHAIR.

Mr. W. E. GARFORTH read the following paper :—

SUGGESTED RULES FOR THE RECOVERY OF COAL-MINES AFTER EXPLOSIONS.

BY W. E. GARFORTH.

INTRODUCTION.

In an address which, as president of the Midland Institute of Mining, Civil and Mechanical Engineers, the writer had the honour to deliver in August, 1893, he drew the attention of members to the necessity of formulating a number of rules to help in recovering a mine after an explosion. The hope was expressed that, with the aid of the societies forming The Federated Institution of Mining Engineers, a sufficient number of individual experiences might be collated to permit of the issue of special and local rules for the use of those (especially the younger members) who might be suddenly called upon to render assistance in an accident attended with serious loss of life. In July, 1891, when giving evidence before the Royal Commission appointed to consider the question of Explosions from Coal-dust in Mines, the writer made a similar suggestion, and offered to submit to the Commissioners certain rules which had proved of service in exploration-work, but they were considered outside the scope of their enquiry. Indeed, from the time of the Astley pit explosion in 1874, when 62 lives were lost, the writer has felt the need of having, in a concise form, rules and suggestions similar to those now proposed, which, in the form of a handbook, could be considered and quickly grasped while on the way to the scene of some colliery disaster.*

* The time required to read aloud the suggested rules is rather less than 30 minutes, and the scientific aids about 10 minutes.

Considering the full and detailed accounts which have been written, during the last century, by some of the most experienced and scientific men of this and other countries, to explain the cause of colliery explosions, and suggesting precautions to prevent their occurrence, it seems somewhat strange that the mining world does not to-day possess a code of rules, which would be of practical use in a time of great excitement and confusion such as usually follows a colliery explosion. The reason for this omission may be that explosions occur so seldom that a manager prefers to turn his attention to the prevention of ordinary accidents, rather than to occupy himself with matters which are dependent on an explosion which may never take place; or, he may have been so overcome and wearied by the exertions attendant on the work of exploration, that he could not record the details, and afterwards the recollection of having lost so many good and brave men made it too painful a subject to discuss. Those members who have never passed through the sad experience and the terrible anxiety following an explosion, but have taken every possible precaution to avoid one, may say that the writer's propositions are unnecessary, and that there are at the present time too many restrictions in carrying out the several Acts of Parliament relating to colliery management. In reply, it may be pointed out that previous to 1851, or before serious legal restrictions were placed on the getting of coal, the loss was 1 life for 219 persons employed, whilst last year (1896) the loss was only 1 life for 675 persons employed or 190,596 tons of coal raised.

Unfortunately, explosions are not things of the past; they continue to occur in spite of all the skill and care of colliery officials, and at the pits which are considered "the safest in the district." It is often the unexpected which happens, and it is therefore prudent to be fully prepared for every emergency, especially having regard to recently proposed legislation.

The best time to judge of the utility of formulating rules, is not when all connected with a colliery is working satisfactorily, but rather when standing near the mouth of some pit which has recently fired, surrounded by a crowd of anxious relatives waiting in dreadful suspense. At the same time, scores of men, with hearts as brave as ever beat on land or sea, are offering to face any danger in a noxious atmosphere, with a miserable light, and no means of escape except by a deep shaft, which with its attendant appliances may have been more or less damaged by the force of the explosion. Such men the poet Wordsworth describes:—

He holds no parley with unmanly fears;
Where duty bids, he confidently steers;
Faces a thousand dangers at her call,
And, trusting in his God, surmounts them all.

With such a fearless body of men, the manager, in his anxiety not to incur the risk of further loss of life, naturally hesitates as to the best course to take. Although there can be no fixed rule, and each case must depend upon circumstances, still, if the manager thus suddenly called upon had before him, in the form of suggestions and sketches, a knowledge of the means which had proved successful at a neighbouring colliery some years before, or the mistakes committed at another colliery, by which a second explosion and further loss of life occurred, it would help to show him what to do and what to guard against. It might also tend to reduce the feeling of helplessness more or less present, when man is face to face with a calamity brought about by the forces of nature. Indeed, it sometimes happens that the shock caused by the sudden news of an explosion interferes with that clearness of judgment which is essential at such a critical moment.

Statistics show that explosions, previous to 1860, resulted in the loss of 2·98 lives per explosion, and since that date the loss has been at the rate of 6·25 lives per explosion. This increase is partly due to the increased depth of the mines from the surface, which necessitates the adoption of the longwall-pack-gate system of working, and to roadways now being made through the goaf, and often resting on timber. The roadways are also much longer than formerly, and covered with a greater quantity of coal-dust due to increased traffic; consequently when timber is blown out by an explosive blast of greater force, the falls are heavier, and the pit is, therefore, more difficult to recover.

For many years past, the writer has given general assistance at several collieries where explosions have taken place; and, some years ago, he had the daily responsibility, extending over several months, of recovering a mine situated at a depth of 1,260 feet from the surface. This was a difficult task, as old workings existed of nearly 1,000 acres in extent, with roadways driven through the goaf, resting principally on timber, the displacement of which caused falls of roof 16 to 18 feet high, and in addition to other difficulties several fires had to be extinguished. The work of recovery was successfully carried through without any serious drawback, and the normal output of the pit was restored in a comparatively short period. As the result of such experience, the writer ventures to submit a number of rules or reminders for the consideration

of the members. It will be noticed that some of them are such as would naturally occur to the mind in its normal condition as the best way of meeting difficulties. But, unfortunately, the mind is at such times not found in its ordinary state, consequently certain instructions which should have been issued at the outset are overlooked, and when given later they do not possess the same value.

In this age of science, strength of muscle is as burnt flax to beaten iron in comparison with strength of mind. The engineer can spare the former, but must possess the latter; he must also have a clearness of perception, and a grasp of mind which overlooks no difficulties, but provides every available means of overcoming them. Temporary reverses and discouragements should nerve him to increased efforts, and strengthen his resolution to overcome them. No merchant at his books, nor mathematician at a problem, should display a greater regard for minute details than the manager or chief of an exploring party.

It would facilitate the working of such rules, if members in coal-mining districts, which in the past have been subject to colliery explosions, would give the benefit of their experience to members in other districts hitherto free from such disasters. Difficulties in these latter may arise in the future, consequent on deeper mines being worked. In any case, the formulation of rules might be the means of increasing the standard of discipline. A discussion of them might also be the means of saving time when even a few minutes are of vital importance. For instance, if two or more members met at the scene of an explosion, then the remembrance of the reasons which led to the formation of certain rules at an Institute meeting, would assist them in arriving at a decision with greater promptitude than if they had not previously discussed the subject.

The alternative is to continue in the old-fashioned way. This means that mining engineers and colliery officials of the future will have to incur responsibility (sometimes to close a mine) with imperfect information before them and to suffer the same mental strain as that which their predecessors have undergone. In addition to which, there are the increased responsibilities consequent on the enquiry usually held by the Home Office, claims for compensation under the Employers' Liability Act, and the greater losses resulting from the stoppage of larger collieries. This policy, it must be admitted, is not in keeping with the various practical and scientific improvements which in recent years have been carried out at many collieries.

What is desired is a thorough consideration of the question. There

may be difficulties, but "obstacles to a true policy only test its validity." The writer trusts that the members of The Federated Institution of Mining Engineers will, by the help of some of the fundamental rules here suggested, construct a general code into which each mining district will incorporate other rules applicable to flat or inclined coal-seams and local conditions which can be supplemented afterwards by a number of sketches to aid the eye.

If the writer's proposal be carried out on such lines, it is to be expected that, besides reducing the number of explosions by guarding against them, and recovering the pits more systematically and with less risk to those engaged, there will be a consciousness in the minds of both the older and younger members of having supplied a want which has long been felt, and in having carried out a scientific work by which colliery officials will be saved many of the anxieties and difficulties which have been suffered in the past.

It is hoped that these rules or reminders will receive the approval of H.M. inspectors of mines, who have already contributed valuable papers to and taken part in discussions connected with The Federated Institution of Mining Engineers. In connexion with explosions, they have had special experience, and mining engineers and colliery managers have cause to feel deeply indebted for valuable advice received from them during times of great anxiety.

With the view of testing some of the suggested rules, without waiting for another accident to take place before their applicability can be discussed, the writer proposes to describe in detail the means which were adopted to recover the Altofts colliery, referring at the same time to those rules which were found most useful during the explorations.

The following is a summary of the suggested rules, etc., in this paper :—

Suggested Precautions to be taken by the Manager before an Accident.

Appointment of emergency officials, including ambulance corps.—Rules 1, 2, 3 and 4.

Preparation of mechanical and other special appliances.—Rules 5, 6, 7, 8 and 9.

Arrangements for restoring ventilation.—Rules 10 and 11.

Sections and drawings of surface appliances, particulars of downcast and upcast shafts, plans of underground roadways, and system of ventilation.—Rules 12, 13 and 14.

Arrangements for safety-lamps, ambulance requisites, schedule of stores, and position of same in mine.—Rules 17, 18 and 19.

Instructions to officials and workmen.—Rules 15, 16 and 20.

Suggested Rules for Guidance after an Explosion.

Duties of surface and underground officials, including ambulance corps.—Rules 21, 22, 23, 24, 25, 33, 34 and 35.

Plans, registers, and instructions.—Rules 26, 27, 32, 37 and 73.

Means for quick descent into mine and precautions to be observed in shaft.—Rules 5, 6, 7, 8, 28, 29, 30 and 42.

Arrangements required for and precautions to be taken by first exploration-party.—Rules 31, 36, 62 and 65.

Precautions to be observed by explorers generally.—Rules 38, 39, 40, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 63, and 75 to 89.

Dangers to be guarded against.—Rules 43, 52, 53, 58, 66, 67, 68, and 75 to 89.

Transport of injured and dead.—Rules 59, 60, 61, 63, 64, 74 and 75.

Suggestions for restoring ventilation.—Rules 41, 70 and 72.

Extra precautions in case of fire.—Rules 65 and 69.

Recovery of roadways, bratticing, etc.—Rules 76 and 77.

Supply of food and restoratives.—Rule 71.

Scientific aids.—Rules 78 to 91.

Plans and sketches of hypothetical cases.

Detailed description of Altofts colliery explosion.

Suggested Precautions to be taken by the Manager before an Accident.

(1) (*a*) During the ordinary working of the colliery, the leading officials should be requested carefully to consider not only how to avoid ordinary accidents, but to anticipate the means which should be taken in the event of an extraordinary occurrence, such as an explosion, with the view of making beforehand any necessary preparations in their respective departments.

(*b*) In case of a serious accident, it is well to realize from the commencement that the work of exploration may extend over many days and, perhaps, weeks. The best available men should be equally distributed over three shifts. It is impossible to foresee certain difficulties, but when they do arise there should always be fresh and energetic men with cool heads ready at hand. Such men have succeeded when those in an exhausted condition have failed.

(2) (*a*) In addition to the certificated manager, under-manager, enginewright, and other officials whose duties are defined in the Coal Mines Regulation Acts, the following heads of departments are suggested to carry out the work of exploration :—

(*b*) Two (night and day) special underground officers to co-operate with the manager and under-manager respectively. A written authority should be held by some of the officials to show that, in case of an explosion occurring whilst the manager and under-manager are in the mine, they are deputed to act pending the arrival of H.M. inspector of mines.

(*c*) Two (night and day) special surface officers to carry out the manager's orders during his temporary absence.

(*d*) *Exploration Officials.*—Officials who have during the ordinary working of the colliery become acquainted with the various underground workings, disused roads (portions of roadways where the roof is bad and rests principally on timber), and who have qualified themselves generally to act as leaders of exploration-parties or assistants to mining engineers.

(*e*) *Chief and Chief Assistant of Ambulance Corps.*—These officials, it is intended, shall render first aid to the injured, carry out the doctor's instructions, be responsible for recording lists of the injured and the dead, take full particulars for identification, and answer enquiries from relatives respecting the injured and dead.

(*f*) Two (night and day) ventilation and recording officials and assistants.

(*g*) Two (night and day) supply officials and assistants to supply restoratives, refreshments, timber, brattice-cloth, etc.

(3) Considering the unexpected work and anxiety devolving on the manager and chiefs of exploring parties, it is most important that as many details as possible should be carried out by the officials named.

(4) The appointment of the before-mentioned officials should be made in writing, and should hold good until cancelled in writing. Even amongst officials excitement tends to produce confusion, which it is advisable to subdue as soon as possible.

(5) (*a*) Consider, during the ordinary working of the colliery and with the assistance of the leading surface and underground officials, the quickest and safest mode of descent into the mine, on the assumption that the usual winding arrangements are rendered useless, or temporarily disorganized at both downcast and upcast shafts.

(*b*) It is suggested that cross-girders and other necessary appliances should be placed in the pit-head gear to carry a suitable pulley. Also that arrangements should be made to test whether timbers placed across

the shaft would carry such a pulley in case of accident to the head-gear. Independently of an accident from an explosion, this pulley would prove useful should the cages get jammed in the shaft.

(6) Arrange in a suitable position, in line with this pulley, and so that it would not be affected by an explosion, a winding or capstan engine and drum with a sufficient length of rope to reach the lowest part of the shaft. This rope should be coiled on the drum, and not left hanging in the shaft. This engine may be arranged to do other work, such as electric lighting, etc. If the shaft be not too deep, it might be possible, assuming that all winding apparatus be destroyed, to fix temporary gear and attach the winding-rope to a locomotive.

(7) Prove whether the hammer-and-plate signal can be heard from top to bottom of the shaft. If not, arrange special electric signal with cable fitted on reel. Test these appliances every three months or oftener.

(8) Prove the utility of "cradle," "horse" or other appliance for lowering shaft-men. Leather breeches and belt, combined with a wooden seat with attachments to main rope, may be mentioned. Bag with ambulance and other small requisites should be conveniently arranged to hang below the seat, which can be made in the form of a box with compartments. Two emergency officials in addition to the regular shaft-men should be practically qualified to descend the shaft. A serious risk is involved in lowering a safety-lamp.

(9) Connect the water-pipes from the surface to the mine, with intermediate branches and valves, in one or both shafts, for use in case of fire. These pipes would be useful for supplying water to underground stables, or for watering main-roads where extra pressure is required, or for extinguishing any fires connected with insulating-boxes of electric cables.

(10) Have on hand an engine capable of driving a self-contained fan, say 10 feet in diameter, and sufficient baulks of timber to serve as a foundation for the same, etc. This plant is only required in case the ventilating power is a furnace, or in the case of a fan erected before the passing of the 1887 Act and not arranged so as to remain uninjured by an explosion.

(11) Arrange for the fixing of the engine and fan, and have detailed drawings prepared, with figured dimensions of the same, also arrangements for connecting steam-pipes between the engine and one or more ranges of boilers.*

* Probably, in the near future, groups of collieries will establish and support central district depôts for the storing of "Colliery accident apparatus" and the training of men to explain and use them. Such a set of apparatus should include a specially-designed self-contained fan, equal to exhausting 90,000 to 100,000 cubic feet of air per minute, Fleuss apparatus or pneumatophor, a quantity of light air-pipes, etc.

(12) Prepare three cloth tracings from the working-plan every six months showing all the roads then open, the names of all main-roads and numbers of the gate-roads, position of overcasts, doors and sheets. One of these tracings should be given to the under-manager and the other placed in a special drawer in the office labelled, say, " Emergency drawer." When this plan becomes too large for easy reference underground it should either be made on a smaller scale or divided into sections. These tracings, being made on cloth, do not easily tear, and the details can be better seen in the pit when placed in front of a safety-lamp. These plans should show the underground workings only, having no regard to the surface, so that a neighbouring colliery official engaged on the exploring staff would get no information as regards boundaries of coal unlet, thickness of barriers, etc.

(13) Prepare a vertical section showing the mines worked and the various mouthings in the shafts and all connexions between the different mines, and have prints of this section kept in the emergency drawer.

(14) Fix on the pit-bank an outlined plan of the mine-workings with the main intake and return air-roads painted in different colours, to help workmen to know the mine.

(15) Accustom the men periodically to travel certain roads which they are not in the habit of doing, so that they may learn that there are more ways than one from the coal-face to the shaft.

(16) Place finger-posts or boards in the main-roads showing, during the ordinary working of the colliery, the direction to the upcast pit or other second outlet. Many lives have, doubtless, been lost in the past by not knowing the different ways to the pit-bottom.*

(17) Have all lamp-rooms on the surface, not only for increased safety, but so that no difficulty may be experienced in getting safety-lamps for the explorers.

(18) Have an ambulance corps formed in connexion with the colliery. See the special instructions issued by the St. John's Ambulance Society, which includes the method of producing artificial respiration. Regular practice in this exercise is essentially necessary. Examinations of the different boxes on the surface and underground, containing ambulance stores, should be made every three months.

(19) (*a*) Provide a complete set of ambulance requisites, and place the chest or box containing them in a convenient and dry place near the

* Some men have saved themselves after an accident, whilst others with an equal chance have lost their lives, and it may prove useful to collect information from survivors of colliery explosions as to the means they adopted

pit. The following articles are suggested:—Different sizes of splints; bandages; cotton wool; 6 rugs or blankets; several flasks fitted with suitable cups and straps for carrying them; water-bottles with straps; supply of brandy; cans and cups suitable for supplying hot coffee, hot and cold tea without sugar; cans for oil and lime-water; 6 oxygen-cylinders, each capable of holding 3 to 4 cubic feet, sufficient, say, for two men (these cylinders should be made by a respectable firm, properly tested and annealed); 12 small flasks of compressed oxygen; 3 stretchers (made from two poles and brattice-cloth); 2 coils of rope of sufficient strength to support a man; 6 coils of stout cord; 6 fire-extincteurs; Fleuss apparatus or pneumatophor; and ambulance-waggon. The colliery doctor may desire to have a separate box to contain drugs for his own use, emetics, injections, etc.

(*b*) Provide a similar box, containing most of the articles mentioned, for use near the bottom of the pit, also several portable electric lamps.

(*c*) It is also convenient to have some of the foregoing things placed in a small box at some of the main pass-byes or junctions near the coal-face, together with a stretcher (made from two poles and brattice-cloth) and labelled, "ambulance stores." The position of these stores should be shown on the exploration-plan.

(20) Post a copy of these recovery rules on the pit-bank, with any further special information suitable for any particular colliery.

Suggested Rules for Guidance after an Explosion.

It is understood that if any of the following "Recovery Rules" should conflict with the General and Special Rules referred to in the Coal Mines Regulation Acts, 1887 and 1896, or any Parliamentary or Home Office orders, the latter shall take precedence. It is likewise expected that the consideration of these rules or reminders will not reduce, but rather increase the heroism and sympathy shown at previous colliery explosions.

(21) Nothing connected with the working of the mine must be disturbed or removed during the work of exploration, unless absolutely necessary for the safety of the explorers, the rescue of the survivors, or the recovery of the victims. It is to be observed that all and full evidence is required by H.M. inspector of mines to assist in the enquiry to be held to discover the cause of the accident.

(22) Wire for H.M. inspector of mines, and send carriage if at night and within driving distance.

(23) Send for all emergency officials not in the mine, and for the colliery doctor.

(24) Assign to each official his duty and give him a signed order, which shall remain in force until cancelled in writing.

(25) Confer with the chief (or his assistant) of the ambulance corps:—(*a*) To appoint two members to descend with first exploration-party; (*b*) to prepare restoratives and necessary appliances; and (*c*) to receive sufferers, etc.

(26) Send for the plans from the emergency drawer and arrange for more copies being traced on cloth.

(27) Have the specially prepared colliery plan and section of the mine laid out in a room in the offices, where all persons engaged in leading the exploration-parties may have full opportunities of examining them (Rule 12).

(28) Examine the surface-arrangements at both upcast and downcast pits. If compressed air is used, consider the effects on the ventilation, assuming broken pipes or joints, also the effect on the ventilation if water connected with pumps is escaping and producing downward currents of air; and also the effect if stoppings connected with other mines are blown out.

(29) If the winding arrangements be disarranged, get ready special means for descending. Amongst other advantages of getting into the mine quickly are:—(*a*) To afford relief to the injured; and (*b*) to extinguish fires which, if allowed to burn, may cause serious complications.

(30) If the fan-drift be damaged, arrange for its immediate repair, first temporarily and afterwards by permanent work. Boards overlaid with brattice-cloth, or with strips of same, are quite sufficient in the early stages of exploration-work when usually only a small quantity of fresh air is required. If the fan be damaged, consider the advisability of using a steam-jet placed at such a distance below the surface that the condensed steam falling back does not impede the upcast current. When properly arranged (economy of steam being of secondary importance) a sufficient quantity of air can be obtained by a steam-jet equal to the emergency, especially if assisted by natural ventilation.

(31) Until the principal roads, etc., near the shaft-bottom have been examined by the first exploration-party and a report has been sent to the surface, it is suggested that the speed of the fan be reduced to two-thirds or one-half of its ordinary speed.

(32) Before descending the pit, the manager should appoint some one to occupy his position in case a serious accident should befall him; he should also arrange that the under-manager shall not be engaged in any specially risky underground work at the same time as himself.

(33) Instruct the two officials (night and day), who shall have full

control on the surface whilst the manager is underground, to immediately arrange for a plentiful supply of non-inflammable brattice-cloth, timber, etc.

(34) Appoint two officials (night and day), who shall take charge of the top of each pit. They shall receive, from the ambulance corps or officials mentioned in the foregoing rule, any article which requires to be sent down the pit; they shall promptly forward messages received from below, etc.

(35) Appoint assistant lamp-men, who shall register, in addition to the workman's ordinary check, the names of all parties descending or ascending the pit, with the time of such visits.

(36) From the ambulance-store on the surface (Rule 19) prepare ready for first exploration-party:—Approved self-extinguishing safety-lamps to test for gas; electric lamps for good lights to examine shaft, etc.; restoratives—comprising flasks of brandy with cups and shoulder-straps, and water ambulance-bottle with stopper arranged to serve as cup; lengths of rope to carry men, in case the cage cannot reach the bottom of the shaft due to the conductors being forced out of position or to wreckage; flasks of carron oil (raw linseed oil and lime-water) for burns; 2 cylinders of oxygen; 6 small flasks of compressed oxygen; cotton-wool; three rugs; note-books; and if signals be destroyed, special telephone and cable or hammer-and-plate signal. It is essential that the person taking charge of the cylinders of oxygen has previously received practical instruction how to administer the gas.

(37) Place a notice-board in a conspicuous position on the pit-bank with the following cautions:—"Real courage does not consist in being careless of danger, but in being quick to face and disarm it." "Courage without caution is dangerous." "Caution without courage is contemptible."

(38) If mining engineers or managers from neighbouring collieries are assisting, arrange to have one or more emergency officials with each party to explain the details of the pit. If principal officials have been rendered helpless or killed and strangers are called upon to attempt extra work, it is suggested that the explorers should be provided with bags of paper or some other heavier material to identify their route, as the appearance of a road is soon changed by heavy falls and wreckage.

(39) Arrange for an exploration-party of 8 persons (including either the manager or the under-manager) to descend the pit as soon as appliances are fit. Two competent men should return with information for H.M. inspector of mines and for the consulting engineer on their arrival, together with instructions for additional men when needed.

(40) Let all appointments of the leaders of each exploration-party be in writing. If possible give written instructions as to the district that they are to explore and the work that they are to perform. Difficulties have arisen at previous accidents through misunderstandings which, it can be proved, would have been avoided if this rule had been carried out.

(41) The system of ventilation, having been approved in consultation, must not be altered whilst explorers are in the pit. In an early stage of the exploration, extra care is necessary in arranging any system of ventilation, owing to the reduced water-gauge or slight difference of pressure between the intake and return air-currents. Some districts, owing to the fear of undiscovered fires, may have to be recovered by a current insufficient to move the anemometer.

(42) Old connexions with the shafts should be examined to see whether stoppings are blown out, and (if approved on consultation) arrange to repair them forthwith. There may be a disused connexion between the upcast and downcast shafts nearer the surface than the source of the explosion.

(43) All survivors found near the pit-bottom should, on the arrival of the first exploration-party, be sent out of the pit as soon as possible. Be prepared for great excitement among these men, even to the extent of their struggling to get into the first cage.

(44) Previous to any party leaving the pit-bottom, the full object of their journey must be recorded in a note-book to be kept for the purpose and left in the deputies' cabin near the shaft. Should any delay occur a search-party will be able to follow. This record will also help to maintain strict discipline.

(45) On no account must any man explore alone, even on the shortest journey. This rule is intended to prevent relatives and others from causing unnecessary risks. As soon as certain parts of the pit are pronounced safe, the management will give directions for the convenience of those engaged.

(46) Each exploration-party should consist of at least 6 men, and 2 men should be sent back to the pit-bottom, ½ hour after leaving, to report. This arrangement not only gives information as to the progress being made and difficulties experienced, but enables those in authority to form some idea as to when the next relief-parties will be required and the materials wanted. It also leaves the party sufficiently strong to continue the exploration or carry one of the party back in case of disablement. A small telephone and light cable may be found useful under certain conditions.

(47) Remember, it is during the first few hours, that lives are most likely to be saved if they can be reached. If the downcast shaft be inaccessible, the question of descending the upcast shaft should be considered.

(48) Do not, during the first 24 hours, spend time in recovering the dead if there be any chance of saving life. The main objects should be :—(*a*) To save life ; (*b*) to prevent further loss of life ; (*c*) to recover the dead ; and (*d*) to restore the pit for regular work.

(49) Have as few men as possible in the pit, until satisfactory evidence has been gained that there is no risk of a second explosion.

(50) In advancing, the party should be, as far as possible, in single file, the second official in charge bringing up the rear.

(51) Loss of life to explorers may perhaps be avoided by remembering the dangers of (*a*) after-damp, (*b*) falls of roof and sides, and (*c*) underground fires and consequent risk of a second explosion.

(52) Parties should be careful not to explore too far at once, even when taking air with them. The force of the explosion may have forced the after-damp into the interstices of the goaf, from which it may gradually exude into the roads through which the party may have to return.

(53) Only the leader of each search-party should test with his safety-lamp for gas : one of the party may accompany him, but the rest should wait a reasonable distance away. Only self-extinguishing safety-lamps should be used. Remember that the safety of a mine is only equal to the most unsafe lamp or most careless man in it, in the same way that the strength of a chain is only equal to the weakest link.

(54) Each person is reminded that he is responsible for his own safety-lamp, and warned to prevent its exposure to test gas unless absolutely necessary.

(55) If an explosive atmosphere has been detected, it must not be re-tested until means have been taken to render it harmless.

(56) Do not let the safety-lamp be the final guide as to the absence of after-damp. Quantities smaller than the lamp can detect may prove fatal to human life. (Scientific aids, No. 82.)

(57) Explorers must avoid recklessness when in the presence of either carbon-monoxide or carbon dioxide gases. The latter gas is not so poisonous as the former, but it has a directly poisonous effect on the system. (Scientific aids, Nos. 78 to 84.)

(58) Remember if one person is overcome with after-damp that he is not only thrown out of action, but at least three others are required

to carry him back. If it be found necessary to fix a sheet, etc., in a doubtful atmosphere the person making the venture should repeatedly call to those in the near vicinity to indicate his safety.

(59) Prepare stretchers, blankets, etc., for carrying survivors; also have ready restoratives (Rule 19). The most convenient stretcher is made from brattice-cloth and two poles.

(60) Wrap up men who have been in after-damp, and as far as possible prevent them from exerting themselves. At the same time keep them awake, even to the extent of walking them about supported by two men with arms over each shoulder. If they are very much exhausted, supply oxygen, and consult a doctor as soon as possible.

(61) The dead bodies should be wrapped in brattice-cloth or flannel, and sent out to the surface on stretchers. If they have been in the mine several days and decomposition has begun, provide wooden shells and supply the men handling them with disinfectants and leather gloves with long gauntlets to protect them from blood-poisoning. Leave the brattice-cloth with the body. Afterwards, thoroughly disinfect the place where the bodies have lain.

(62) If very little damage be done near the pit-bottom, and the signs of fire, force, falls of roof, and after-damp—the usual evidences of an explosion—are not met with to a serious extent along the main roadways, and the reports from the various main air-returns are satisfactory, then send word to the surface, with the view of getting additional exploration-parties sent into each district.

(63) One of each exploration-party should take notes of the position of the bodies, state of the timbering, tubs, doors, air-crossings, safety-lamps, tools, machinery and attendant appliances, coal-dust, sooty condition of roads, falls of roof, etc., as such evidence may prove useful at the official enquiry.

(64) If the victims are very numerous, arrangements should be made for numbering each corpse (attaching a tub-motty is suggested), at the same time showing on the exploration-plan where each body was discovered. Particular notice should be taken of the clothing, especially of the boots, leather straps, etc., and things which do not soon decompose. Many painful scenes have taken place amongst supposed relatives by neglecting this precaution.

(65) If the force of the explosion has blown out the separation-doors and overcasts, do not restore them immediately, as there may be undiscovered fire. Place thermometers in all the principal roads to test for any alteration in temperature, and furnish reports to chiefs of explora-

tion-parties every two hours, or oftener, if necessary. Before making any important alteration, consult, if possible, the manager or under-manager, who have information respecting details of the mine not generally known.

(66) Use, if possible, non-inflammable brattice-cloth. Brattice-cloth is of little use except for short distances, especially on a road rendered uneven by large falls. Therefore have ready or send immediately for some 12 inches air-tubes, or a larger size if they are in stock. If any difficulty occurs in ventilation and there are no indications of fire, and compressed air be at hand, use a jet in the air-pipes on the steam-injector principle.

(67) If the main intake-airways be blocked by heavy falls, which may require some days to penetrate, consider the advisability of going along the main return-airways, taking air-pipes as the exploration-party proceeds. In some instances this precaution would have saved a number of lives, but to do it safely the intake road should be stopped-off, otherwise after-damp may be brought suddenly on to the explorers.

(68) Remember instances can be given showing that where the force of the explosion ceases there is very likely to be a fire, especially if there be doors, timber, or a feeder of gas near the point.

(69) Should an increase of temperature take place or fire-stink be noticed, all men must be immediately withdrawn and a report made to the manager. It will then be decided to: (*a*) shut off the district by setting tight sheets or stoppings in all intake roads, and tight sheets with valves in the return roads (these valves are intended to allow the gases to escape should they be given off under pressure, and to serve for examination of the return air); (*b*) try and get to the seat of the fire; or (*c*) close the pit by earth or water-tight stoppings, or a combination of same.

(70) If no fire-stink be noticed, then, after consultation, restore overcasts and separation-doors with timber and brattice-cloth in such a manner that, if it becomes necessary to produce a stagnant atmosphere, the brattice-cloth can be instantly removed, and the air allowed to pass direct to the upcast shaft. As the work of exploration proceeds, it will be found convenient to substitute doors. Brattice-cloth stoppings can be improved by leaving the cloth sufficiently long to cover it with rough and fine dirt, with packs of dirt at the sides. The same remarks apply to double stoppings, with the additional cloth and cross-bar. "Hurdle" brattice, that is brattice-cloth placed within 1 or 2 feet from the roof,

and arranged to be tight at the bottom, has proved useful in clearing away gas or keeping it from passing to a goaf fire.

(71) Appoint men in each shift to arrange for restoratives and food. No person shall take stimulants down the pit unless supplied by the person in charge or on a written order from those in authority.

(72) The quantity of air passing in each split should be measured as often as convenient. and especially after any alteration has been made in the sheets. Such measurements should be recorded in a book kept near the pit-bottom, so that it may be regularly examined by the leaders of the exploring parties.

(73) Register the temperatures in the main return and intake airways, and report in accordance with preceding rule.

(74) If the number of sufferers is likely to be large, arrange a temporary hospital, and also a cool place for receiving the dead bodies.

(75) Send out dead horses as soon as convenient, as they soon become very offensive. Provide the men with leather gauntlets; use the broad straps belonging to cart-horse gears by placing them under the bodies, which afterwards raise, by pulley-blocks suspended from the roof or from a temporary tripod, to a sufficient height to allow a timber-tram to be placed underneath. The dead body can then be sent forward to the dirt-bank on the surface without further handling. The stables should be afterwards disinfected.

(76) After it is known that there is no danger of a second explosion and when ventilation is partly restored, the roadways should be made quite safe for travelling.

(77) To facilitate the recovery of the pit for work, and to avoid sending large quantities of dirt to the surface, prepare a section to show the height of certain roads with the view of seeing if some of them will admit of being raised throughout, so that part of the *débris* from falls will raise the road where no falls have occurred.

Scientific Aids.

The following aids have been collected from the reports of H.M. inspectors of mines, including remarks by Mr. Joseph Dickinson. late H.M. chief inspector of mines, and from the writings of Sir Frederick Abel, Messrs. W. N. Atkinson, J. B. Atkinson, and W. Galloway; Professors P. P. Bedson, F. Clowes, and J. S. Haldane, besides other members of The Federated Institution of Mining Engineers, who have done so much to give valuable information for the prevention of colliery accidents.

Scientific aids are given as a warning to explorers to show that the strongest men have often succumbed to the poisonous effects of gases met with in mines.

(78) The presence of carbon monoxide in after-damp causes, it has been estimated, 70 per cent. of the deaths from explosions. It induces oxygen starvation by strongly combining with the colouring-matter of the red blood-corpuscles. The function of this colouring-matter, which is to loosely combine with and carry oxygen from the lungs to the various tissues of the body, is destroyed by this combination with carbon monoxide. Any proportion above 0·2 per cent. of carbon monoxide in the air is decidedly prejudicial and may be dangerous.

(79) Deaths from carbon-monoxide poisoning may be recognized from the colour of the blood, which is bright scarlet, and not blue as in carbon dioxide poisoning. The bodies lie lifelike, with the lips and tongue pink. A little blood from such a body, if diluted about one hundredfold with water, is pink, differing from diluted normal blood, which is light brown. This test for carbon monoxide in the blood depending on its change of colour, has been proposed by Dr. J. S. Haldane. It should be made in daylight, the diluted blood being compared with similarly diluted normal blood in narrow glass tubes.

(80) The symptoms of carbon-monoxide poisoning, which are painless, are somewhat in the following order:—Tendency to dizziness, palpitation, shortness of breath, drowsiness, a giving way of the legs, loss of consciousness.

(81) When a man's blood has absorbed much carbon monoxide, he may on reaching fresh air again become worse and lose consciousness. He may die if the exposure has been long, even after the blood has been freed from the poisonous gas. Possibly this result is due to the chilling effect of the fresh air when the vitality has been lowered by the poisonous gas.

(82) The percentage of carbon monoxide necessary to cause death cannot be detected by the ordinary oil safety-lamp or directly by the senses. It can be detected by the standard hydrogen flame proposed by Dr. F. Clowes, but the best test consists in shaking the air with diluted normal blood and noting the change of colour from light brown to pink as suggested by Dr. J. S. Haldane.

(83) Persons have been found alive, if fresh air has at once replaced the after-damp. Air must be breathed for an appreciable time before carbon monoxide is absorbed from it by the blood.

(84) Carbon dioxide is not as dangerous as carbon monoxide, and is not directly poisonous. If more than 5 per cent. be present, it produces a special effect on the system. Death caused by this gas is not merely due to the decrease of oxygen in the air, since carbon dioxide lowers the vital-activity even if inhaled in small quantities below 5 per cent., proportions above 5 per cent. produce a rapid effect when breathed.

(85) Mr. W. Galloway stated that 1 volume of fire-damp to 14 volumes of air is slightly explosive, and 1 volume to 15 volumes is inflammable also; and 1 pound of coal-dust to 160 cubic feet of air is required to form an inflammable mixture.

(86) The proportion of fire-damp required in a mine to bring coal-dust readily into operation as an explosive material, when thickly suspended in air, borders upon, and is even sometimes below, the smallest amount (about 2 per cent.) which can be detected by a safety-lamp.

(87) Any gas or vapour which can be kindled or burnt in air may give rise to danger. If gas be mingled with air in the requisite proportion, and kindled, it may acquire the power of burning rapidly, and an explosion may be the result.

(88) Methane or fire-damp when lighted from below has its lower explosive limit when 5 per cent. is mixed with air; and its upper explosive limit occurs when 13 per cent. is so mixed. If ignited from above, the lower and upper percentages are 6 and 11 respectively, and all proportions between these limits are explosive.

(89) The presence of a large proportion of fine coal-dust in the air renders the flame-test so luminous that no cap can be seen even when gas is present. A very dusty atmosphere will render gas-tests impossible by all the forms of testing-apparatus known. No interference may arise from the amount of dust ordinarily met with in air of the mine. The greatest amount and extent of violence is always observed on those roads which before an explosion contained most upper dust.

(90) The workman's safety-lamp may be near him but blown down by the great force of an explosion, or left hanging when the force is less, or found some distance from him when he has travelled in the dark and died from after-damp; and lastly when no force is evident the lamp may be found hung up with the oil burnt, the victim having died from after-damp.

(91) Some objects may show direction but not force, and *vice versa*. The evidences of the passage of flame are the burning of men and horses, brattice-cloth, and the coking of dust.

(92) Timber, when only partly blown out, is a good guide to the direction and force of an explosion.

Hypothetical Explosions.

To enable the foregoing rules and suggestions to be better understood and more quickly grasped on the assumption that the mind is sometimes sooner impressed by the eye than by the ear, the following sketches of cases Nos. 1 and 2 (Plate XXVI.) have been prepared. The plan and section show at a glance some of the disastrous effects produced, the principal precautions adopted and the dangers to be guarded against.

As already explained in the introductory remarks, it is hoped that members of the Institution who have had special experience in colliery explosions will supplement these examples by hypothetical cases founded upon actual practical experience. Without giving the precise details of any colliery, they can show by a sketch and brief explanation how certain operations were in one instance successful, whilst in another case they resulted in further loss of life, and later experience led to the opinion that the loss of life might have been reduced or avoided.

It is easy to be wise after the event, and just as useless. Every opportunity should therefore be taken to become wise before the event. If the criticism of members be given to such facts as may be presented by the sketches, it is probable that rules will be formulated, which will become so wellknown and admitted that some of them will be applicable under almost every condition, and form precedents similar to those established in other professions.

Case. No. 1.

Fig. 1 (Plate XXVI.) represents a coal-mine in which an explosion has taken place at a depth of 1,260 feet. The indications on the surface are :—Both downcast and upcast shafts have been disorganized, and descent has to be made by temporary appliances. The mouthings connected with other coal-seams have been blown out, and the bottom cage is jammed fast. On reaching the seam, it is found that several men have been killed ; the stables are on fire ; a strong smell of fire is perceived in two return-airways ; there are heavy falls of roof ; on the roads near the shaft a large quantity of after-damp, etc.

The suggestions for the recovery of the mine are|:—Appoint and equip exploration-party ; adopt special means for providing relief to injured, and for descending downcast ; extinguish stable fire with water piped from surface ; do not at first restore overcasts ; erect temporary fan ; ventilate and explore each district separately, and seal off the other parts of the mine (Rules 22 to 30, 1 to 4, 21 to 35, 9, 19, 5 to 8, 65, and 36 to 76).

Case No. 2.

Fig. 2 (Plate XXVI.) shows the relative positions of three shafts, working two coal-seams at different levels, viz., 750 and 1,080 feet. A serious fire has been caused, it is supposed by the accidental upsetting of a paraffin oil-cistern, which was afterwards found on the lamp-cabin floor. The bodies of the lamp-cleaner and hooker-on were found close together.

The indications on the surface comprise the following:—The winding-engineman is unable to move the cage in the downcast pit, the wooden conductors are on fire, and the pumping-pit is not available.

The suggestions for the recovery of the mine are:—Do not prevent smoke coming up the pit which is on fire until all workmen are safe on the surface; allow the fire to burn in downcast shaft, and thereby make it into a temporary upcast shaft, rather than cover over the pit-top and allow the smoke to be drawn through the workings, at the same time, stop the fan and trust temporarily to natural ventilation for the lower mine (Rules 22 to 41, 43 to 62, 64, 69 to 71, and 76).

With respect to other hypothetical cases, it is proposed to introduce them during the discussion or in a supplementary paper.

Description of Altofts Pit Explosion.

The explosion in the Silkstone pit, connected with Messrs. Pope & Pearson's collieries, situated in the West Riding of Yorkshire, occurred on October 2nd, 1886. The depth of the seam is 1,260 feet from the surface. The thickness of the seam varies from 3 feet 6 inches to 3 feet 10 inches, and the inclination is practically level. The output of coal at the time of the explosion was about 1,000 tons per day of 8 hours. Only single shifts of men were worked. The colliery had been working for 23 years without any serious accident. Mueseler safety-lamps were in use at the time of the explosion, but for 22 years previously open lights had been used. The pit-bottom and the roadways leading thereto were lighted by artificial-gas sent from the surface by means of a steam-jet. The system of ventilation was by furnace, the quantity of air passing was 147,000 cubic feet per minute, or equal to 320 cubic feet per minute per man employed, after making the usual allowances for horses, lights, etc.

No accident had occurred either from the furnace, candles, or the gas-jets during the period before-mentioned. The area of the goaf was approximately 850 to 900 acres. The mean sectional area of the main haulage roads was about 54 square feet, and of the gate-roads and

crossgate-roads, 44 and 50 square feet respectively. The system of haulage was principally by endless chain. From Fig. 3 (Plate XXVII.), it will be perceived that, after leaving the shaft-pillar, the coal had entirely been worked out on the longwall-pack-gate system of getting all the coal at one operation. At the time of the explosion, the coal-face was respectively distant from the shaft in the direction of No. 1 chain-haulage road, 5,280 feet, the west chain-haulage road, where the explosion occurred, 3,750 feet, the dip-side haulage road 2,400 feet, and the east-side haulage road 2,490 feet. The explosion occurred on a Saturday, about 3 p.m., when all the workmen were out of the pit, except 28 men and boys, who were engaged in repairing certain machinery, widening the west chain-haulage road, and cleaning up coal-dust on the haulage roads. Of this number, 22 were killed or died within a few days from the effects of the injuries received. The usual number of men and boys employed in the day shift was about 400, but they had left the pit about 1·30 p.m.

The indications on the surface that something unusual had occurred were a very loud report and large volumes of smoke issuing from the upcast pit, which latter continued for some time. The flat-sheets at the mouth of the downcast shaft and the timber at the top of the upcast shaft were displaced. On arriving at the pit, the downcast current of air was found to be flowing in the right direction. The engineman discovered, on trying to work the winding-engine, that the cage near the bottom of the shaft was in some way jammed or fastened. It was, thereupon, decided (Rule 6) to use the capstan-engine placed within the foundations of the main winding-engine and ordinarily used for examining the upcast shaft. The rope connected with it was fortunately coiled on the drum and uninjured. This (Rule 5) was passed over a small-diameter pulley on the headgear of the downcast shaft, which had been fixed many years before the accident. If the headgear had been damaged, baulks would have been placed across the pit (Rule 6) and men would have got on the cage at the siding-level. A cradle (Rule 8) was afterwards attached and the enginewright and shaft-man descended the downcast shaft, using a hammer-and-plate signal (Rule 7), owing to the usual signalling apparatus having been rendered useless by the explosive blast. During the descent (Rule 29), it was discovered that a brick stopping at the Stanley Main seam, 240 feet from the surface, and a stopping at the Warren House seam, 456 feet deep, were both blown out. The Stanley Main stopping (Rule 42) was important, as 300 men were regularly employed in that seam. The Warren House seam was

not worked. Nothing else of importance was found to be damaged until reaching a depth of 1,230 feet, when the cage was found to be jammed, due to the explosive blast having displaced the wooden conductors. The shaft-men were able to speak to the survivors (Rule 43), whom they found to be in an excited state.

After the shaft-men returned to the surface, the main winding rope was clamped to timbers across the pit-top and detached from the main drum to enable the engine to be used for lowering the other cage, which was on the surface at the time of the explosion and undamaged. Mr. Fisher (the certificated manager), Mr. Buxton (the under-manager), some of the leading officials, and the writer, then descended (Rule 39) within a short distance of the pit-bottom. By means of a mouthing and ladders some of the injured men were reached, and found to be badly burnt. Two of these men died within a few days, three others who were burnt recovered, the remaining three were uninjured but severely shaken. After sending out the injured men (Rule 43), arrangements were made to extinguish the fire, which was found to be burning near the stables, due it was supposed to the explosive blast having ignited some hay, which in turn had ignited the timber covering leading into the stables (Rule 29). Before the fire was extinguished, the timber was burnt through, and a large fall of roof took place. Fortunately the water-pipes (Rule 9), which were used in connexion with the stables, were soon repaired, and within 12 hours after the explosion the fire was extinguished. It was most fortunate that the explorers were able to get down the pit within a comparatively short time after the accident, as otherwise serious complications would have ensued. Whilst some of the men were engaged with the fire, an examination was made of the pit-bottom (Rule 31). It was then discovered that both main stone overcasts had been destroyed (Rule 65), thereby allowing the downcast air to escape to the upcast shaft, which was situated within a distance of 72 feet. The men who had been engaged near the engine-house, the two furnacemen, and one of the lamp-men, were found dead and severely burnt. The engine-house was badly damaged, and the two furnaces completely wrecked. Seventeen horses in the shaft stables and 35 horses in the east-side stables were found dead. Owing to the water-rings being filled with wreckage, water was running down the upcast shaft. On exploring the main roads, it was found that heavy falls had taken place within a short distance from the shaft, except on the east side, which was a wet road and where no damage was done. The undercast at No. 6 return-airway, and the various separation-doors and overcasts were blown out.

By working night and day, the engine and fan were running on the following Tuesday night. This arrangement provided sufficient air to recover the pit. The details of the various splits of air are recorded in the ventilation diagrams (Figs. 6, 7, 8, 9, and 10, Plates XXIX. and XXX.). Previous to the fan being started, it had been decided to put in tight sheets, in some instances two tight sheets, in the various intake and return-roadways; also to put into No. 6 return-airway an opening 18 inches by 12 inches to serve the purpose of an outlet for any gas (Rule 69) under pressure due to the natural exudation of gas from the coal-face or from concussions of air and gas by falls of roof, and at the same time to indicate whether the gas issuing from the return-airway was explosive or otherwise.

It was realized within a few hours after the explosion that the roadways, some 15 miles in length with hundreds of acres of goaf, would soon become one vast gasometer. It was therefore suggested that the principle which should be adopted to recover the mine should be to gradually drain or exhaust the natural gas from the goaf in the same way that artificial gas is nightly exhausted from the large gasometers in the various towns (Rule 69). As town gasometers are drained by the shops, street lamps, and public places, etc., so in the same way it was argued that the various roadways of the pit might be drained and recovered without accident, provided the pit was divided into panels or districts and each one dealt with separately. All the districts were therefore sealed off by placing double tight sheets and dirt-stoppings at every available opening. It was thought, if any fires existed, that this method of preventing the admission of fresh air would be the means of extinguishing them, and later discoveries proved this action to have been correct. The remains of two fires were subsequently found near the end of No. 1 chain-haulage road (Rule 68).

In consequence of a smell being noticed coming from the dip-side return-airway, it was considered, for several reasons, that this district could not be dealt with by sealing off in the same way as described in No. 1 chain-haulage road and the other districts shown on Fig. 3 (Plate XXVII.). In district A, natural ventilation was taking place, and the smell of fire was each day becoming more pronounced. The system of recording the ventilation, which had been adopted from October 5th following the explosion, showed that a larger quantity of air than was desired was passing down the dip-side haulage road. Every effort had been made to carry out the work of dressing up the falls with as little air as possible, for it was feared that there might be other fires (Rule 41). The registration of the

various currents (Rule 72) was placed in the hands of two assistants, and a report was made to the management every hour of the day and night.

On Friday, October 15th, about 5·20 p.m., the smell of fire becoming stronger, it was decided to discover the cause, and all the men engaged on the roads were withdrawn from the pit. A consultation was held on the surface, and it was decided to make an examination of the dip-side haulage road. At 8 p.m., the writer and Messrs. Fisher and Buxton, accompanied by two deputies, examined the road for a distance of 2,100 feet, to a point where a large fall of roof was met with which completely blocked up the roadway. A further attempt was made by means of the east-side haulage road, and the writer by creeping on his hands and knees at the same time calling out "right" to those in the rear (Rule 58) got sufficiently near to obtain a distinct smell of fire. On returning to the surface at 10·20 p.m., the fan was stopped until the following morning.

This inspection showed that the fire was being supported by natural ventilation—owing to this district lying to the deep of the shafts—and that the gas from the coal-face was gradually accumulating in the roads leading to the fire. It was known that a large area in other parts of the pit was partly filled with explosive gas, and that the shaft-pillar was full of breaks, owing to such pillar not having been left sufficiently large when the seam was originally opened out.

The question of immediately closing the pit and the danger of re-opening it at the expiration of several months, taking into account the 850 acres of goaf and broken condition of shaft-pillar, was compared with the risk of attempting to put out the fire without delay.

Important matters of detail or local conditions, and the experience that the management, officials, and certain workmen had previously gained in extinguishing other small fires entered largely into the discussion. Eventually it was decided to attempt to extinguish the fire as it was impossible to judge how soon the gas, which was being given off from the dip-side unventilated coal-face, would reach the fire. The fan was restarted at 35 revolutions per minute at 10·30 a.m. on Saturday, October 16th. The same party, assisted by ten additional officials and men, succeeded after 12 hours of hard work, and by using a number of fire-extincteurs, in getting within 210 feet of the point where the fire was supposed to exist. A non-inflammable sheet of brattice-cloth (Rule 66) was placed in No. 4 bord to stop any air-current. The fan was stopped on the party getting to the surface about 11·30 p.m. At

12·30 a.m. on Monday, October 18th, explorations were resumed, and it was found on getting to No. 4 bord that the atmosphere in the roadway was in better condition than on the previous Saturday night. This improvement enabled a connexion to be formed between the dip-side and the east-side haulage roads. The fire was discovered at 3 a.m., near No. 31 gate-road, a distance of 2,700 feet from the shaft. The contents of a number of fire-extincteurs were put on the fire. A tight sheet was placed within 1 foot from the roof, so that any gas issuing from No. 23 gate-road was kept from the fire. Owing to the dip-side haulage road not having been injured, water-tubs could be conveyed to the seat of the fire, and as the burning material was scraped or turned over it was at once quenched with water. This operation was carried out by 4 men working together for a period of 10 minutes, during which time the smallest possible quantity of fresh air was admitted. At the end of this short time, the men were so exhausted that 4 others had to take their place. In all 16 men were engaged, and these worked in relays of 4 for periods of 10 minutes, or less time if they complained. At the expiration of 4 to 5 hours they were replaced by 16 fresh men. In this way a large quantity of dirt and burnt timber was turned over and well drenched with water. The work was carried on continuously from Monday at 3 a.m., when the fire was discovered, until 8 a.m. on Tuesday, when it was completely extinguished.

As soon as the fire had been extinguished, officials were stationed to regularly examine the adjoining roads, etc. The remaining portion of district A was recovered on the same day, October 19th.

During the work of putting out the fire, it had been realized that, had an accident occurred, serious inconvenience would have been caused by the principal officials being in the mine at the same time (Rule 32). It was, therefore (Rule 39), decided that during the remainder of the explorations only the writer and manager, or the writer and under-manager, should be engaged on the same shift.

The writer would like to mention that he proved on this as on previous occasions that a pair of ordinary thick trousers proved a better means of testing an almost stagnant atmosphere than the anemometer, as one slight rap of the hand on the trousers raised a cloud of dust which the least current carried away, allowing at the same time an estimate to be formed of the velocity.

On the morning of October 22nd, Mr. Fisher and the writer, accompanied by two officials, explored district B, Fig. 3 (Plate XXVII.).

In travelling Ropers drift, two bodies (Nos. 8 and 9) were discovered. These men were known to have been engaged at 1·30 p.m. on the day of the explosion, in filling dirt and conveying the same to stow up the roadway between the main intake and return-airways, called Ropers drift. The force of the explosion had been sufficient to blow out a 14 inches wall and 6 feet of *débris*, at a point 111 feet from where the bodies were found. As the air in the main west return-airway was found to consist principally of after-damp, it was not until the following day that Mr. Buxton and 4 men were able to travel from Ropers drift to the separation-doors near the upcast shaft. The bodies of the 2 men were taken along this road, having been in the pit for three weeks. Decomposition had taken place, and the bodies were therefore thoroughly disinfected and lifted (Rule 61) on to sheets of brattice-cloth. Each body was then lifted by means of the cloth—which was left with it—into a wooden box, and sent to the surface. It was then placed in a polished oak coffin, left sufficiently large to receive the box. By this method unnecessary handling of the body was avoided, and the risk of blood-poisoning reduced to a minimum.

It was next proved by examination that all the roadways leading to the coal-face in district C were in a satisfactory condition, and therefore the work of getting through the falls on the west chain-haulage road was commenced. The condition of this roadway is shown in the longitudinal section, Fig. 5 (Plate XXVIII.). The various parts of this roadway were sketched before it was restored. The work of getting a road through the large fall proved difficult at first, owing to the small quantity of air which could be got to the men. This was due to leakage in the brattice (Rule 66). Although every means was taken to make it tight by stitching and placing props very close together, it was found that the loose stones under foot allowed the air to escape. It was, therefore, replaced by 2 feet air-pipes (Rule 66), which on this road and afterwards over other large falls proved of the greatest service. The work in connexion with this fall occupied nearly a month, that is from October 25th until November 17th. The work was carried on continuously night and day from 12 a.m. on Monday to 11 p.m. on Saturday. It was eventually got through, and district D was recovered on November 17th. Some of the fallen roadway measured 18 feet high. After getting through the fall, tight sheets were placed in No. 10 intake road.

A few feet beyond Ropers drift, the writer, who was leading an exploration-party, discovered the bodies of several men (Nos. 10, 11, 12, 13, 14, 15 and 16). The position of these bodies (Rules 63 and 64) will be

better understood by referring to Fig. 4 (Plate XXVI.).* Evidence was given at the enquiry to show that they were the bodies of the men who were ordered to blow off about 4½ feet of roadway on the west chain-haulage road, owing to there being considerable friction on the chain and tubs. This was the first time in the history of the colliery that a shot had ever been fired on a main haulage road. The evidence showed that No. 1 and No. 2 shots had been fired at one time, as some of the men were found in a refuge-place immediately opposite; and No. 3 shot, which is believed to have caused the explosion, was fired sometime afterwards. It was from this shot that some of the men were shielding themselves. The roadway for a distance both on the inbye and outbye sides of No. 3 shot was found to be almost undisturbed.

On exploring the main overcast connected with the north-west district, it was found to have been completely wrecked. This district E, Fig. 3 (Plate XXVII.), was recovered on November 18th, and the air was allowed to travel on the west chain-haulage road through various gate-roads and crossgate-roads and back along the main west return-airway. The body of deputy Deakin, which was found a few feet down the north-west crossgate road, was neither burnt nor mutilated, but the mice had eaten part of his body, including the fingers.

Mice were found alive in several parts of the pit, and some of the dead bodies showed that they had been partially eaten by them. Shock appeared to have killed the horses, as they had no sign of being mutilated. A striking instance of this took place on the dip-side haulage road. At the time of the explosion, two men were engaged putting in a brick stopping, a horse was standing near attached to a tub containing mortar, on feeling the blast the men made their way to the shaft in the dark, but in doing so had to get over the horse, which they felt was lying in a dying condition in the roadway.

District F belonging to No. 1 chain-haulage road was recovered on November 19th. The tight sheets, which had been fixed for more than a month after the explosion, were removed, but owing to the smell of fire which the writer and other explorers imagined they perceived, only the least quantity of air was allowed to pass during the exploration. The sheet and relief-valve in No. 6 return-airway being retained, it consequently took a considerable time to force out the after-damp in this road.

* The writer thinks thar it may be of interest to mention that when he saw the plaster-casts in the museum at Pompeii of the victims who were buried in the ashes evolved from Mount Vesuvius (A.D. 79), he was struck with the similarity of the attitude or position of the limbs with several of the victims of this explosion. Both appeared to be shielding themselves from an approaching danger.

The difficulty was further increased by the heavy falls similar to those in the west chain-haulage road. The sides and roof of the roadway had the same appearance as a chimney-flue, all being covered with soot. Bodies (Nos. 18 and 19) of the two young men who were engaged at the time of the explosion in cleaning up coal-dust from the roads were found on this road badly mutilated, showing force and burning.

After proceeding for some distance, hurdle-brattice, that is to say, brattice-cloth (Rule 70) placed 2 feet from the roof and hanging down to the floor, was placed every 9 feet apart. By this means, the current was forced close to the roof. For the reason previously mentioned, that is before the gas could be forced through the limited area of the relief-valve, considerable time was absorbed, especially in overcoming the heavy falls of roof at the intersection of this road with No. 9 crossgate-road. It was not until November 26th that district G between No. 1 chain-haulage road and No. 6 return-airway could be recovered.

On that date, the sheet in No. 6 return-airway, together with the safety-valve, were removed. During the greater part of the explorations this safety-valve was watched day and night, and was the principal guide as to what was taking place in a goaf of several hundred acres. The temperature in the various roads was registered hourly. On the following day, district H between No. 6 return-airway and No. 10 intake was also recovered. On the same day, two sheet-stoppings on the east-side return-airway were removed and the air allowed to circulate round No. 1 to the main east-side return-airway.

The recovery of districts marked I, J, and K, was accomplished on November 29th and 30th. During the recovery of these districts, evidence of fire was found on the road leading from No. 1 chain-haulage road. Considering the heavy falls of roof which had taken place at the various points in No. 1 chain-haulage road, especially the heavy fall referred to at No. 9 crossgate-road, it was seen that the precautions which had been taken to seal off all the districts to the south-east of the west chain-haulage road were most necessary.

Districts M and N lying between Nos. 9 and 38 crossgate-roads, and between the west chain-haulage road and No. 9 crossgate-road, were recovered without any difficulty on December 2nd and 3rd. The body of deputy Lomax was found at the junction of No. 6 return-airway with No. 32 crossgate-road. He appeared as if he had lain down to sleep, his lamp was standing upright with the oil burnt out.

No evidence of the explosive blast or of a destructive force was found after leaving the chain-haulage roads, and no other evidence of fire

was found in the remaining parts of the pit. It was most noticeable (Fig. 8, Plate XXVII., showing falls of roof) that where the chain-haulage roads ceased, the damage ceased in the crossgate-roads, the gate-roads leading to the face, and in various working-places. There was practically no coal-dust after leaving the chain-haulage roads, as the ripping-dirt covered over any small coal left in the process of working at the coal-face. The tramping of the horses on the dirt or warrant floor also tended to cover over any pieces of coal which had fallen from the tubs. All the coal-faces appeared as if the men had left work an hour before, with the exception of the white appearance due to efflorescence.

Ventilation-diagrams and Tables.

The diagram shown in Fig. 6 (Plate XXIX.) records the total quantity of air passing down the downcast shaft direct to the upcast shaft, owing to both overcasts being destroyed. The volume varied from 40,000 to 60,000 cubic feet per minute on October 5th (the explosion occurred on October 2nd). This current was induced by the heat of the brickwork in the upcast shaft. Previous to the explosion, the furnaces were sufficient to produce 147,000 cubic feet of air per minute. After the explosion, the upcast shaft rapidly cooled down, as already explained. In consequence, the ventilating-current reversed several times, whereupon the men were withdrawn and the underground explorations discontinued from October 15th until the 19th. Fig. 6 shows that on October 13th and 14th, 79,000 cubic feet were registered, and it was probably due to this increase that a greater quantity of air was carried by natural ventilation to the dip-side workings. The smell of fire soon afterwards became more pronounced, and subsequently led to the discovery of the fire near No. 31 gateway in district A. After the fire had been extinguished as previously described, it was decided, for fear that other fires might exist, to recover the remaining parts of the pit with the least possible quantity of air.

The diagrams (Figs. 7, 8, 9, and 10, Plates XXIX. and XXX.) and ventilation-tables (Appendix) show the various quantities of air passing on the different roads and on the particular dates, due either to the reduced or increased speed of the fan, or the alteration of sheets, or contracted areas of certain roadways consequent on falls of roof.

The maximum quantity of air used to recover the pit was 83,835 cubic feet with a water-gauge of 2½ inches, as stated in Table III. (Appendix). The firm lines of the diagrams show actual measurements,

and the dotted lines indicate when the ventilation could not be measured, owing to the officials not being allowed to enter the mine for fear of a second explosion, and on Sundays, when the speed of the fan was reduced because no exploration-work was then carried on. In some instances, the volume of air was measured at the top of the shaft.

Fig. 7 (Plate XXIX.) shows the quantity of air passing to the dip-side district, and due principally to natural ventilation. After the fire was extinguished, 5,000 cubic feet of air was sufficient to keep this district free from gas. When the water-gauge was increased, this district gained in proportion, until 15,510 cubic feet was registered.

Fig. 8 (Plate XXX.) gives the quantity passing along the west chain-haulage road during the first few days following the explosion, when the current reversed and the men had to be withdrawn. The dotted line indicates when the registration could not be made underground. When the fan was started, 11,000 cubic feet passed on to this road, afterwards gradually increased, to recover districts D and E, of which this road formed the main intake airway. At the commencement of the recovery, and whilst making a passage through the heavy falls, the return-air from this road was carried through 2 feet air-pipes, which terminated at No. 6 overcast.

The east-side haulage road represented by Fig. 9 (Plate XXX.) was closed until October 15th, when it was opened to reach the fire in district A, which was recovered on October 19th, as already described.

Fig. 10 (Plate XXX.) applies to No. 1 chain-haulage road leading from the pit-bottom to the extreme limit of the southern districts. It was partly closed on October 5th, and was afterwards entirely sealed off until November 18th. The air for the recovery of the districts (F, G and N) marked November 19th, November 26th, and December 3rd, was supplied from the main intake-airway, and the increase shown on the diagram was due to the increased speed of the fan.

It may be observed that, owing to the small difference of pressure between the intake and return air-currents, the same were sometimes almost balanced, consequently the least alteration of the sheets showed an alteration in the different splits.

From Tables I., II., III. and IV. (Appendix), it will be noticed that in the early stages of the exploration-work, the air was allowed to pass direct from the downcast to the upcast shaft. But as more air was required on the several roads, the openings in the overcast sheets were gradually reduced, and no air was allowed to escape. Until all danger from fires had passed, such sheets were, however, so arranged that they

APPENDIX.—Table I.—Recording the Volume of Air per Minute Ventilating the Various Districts.

Note.—The records are given for only every 4 hours, The registrations were, however, made and given to the manager every hour during night and day.

Date, 1896.	Time.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Total Volume of Air.
	a.m.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.
Tues., Oct. 5 ..	10·40	16 093	9,216	1,200	7,700	6,768	—	40,977
	p.m.							
,, ,, ...	1·30	15,015	8,784	9,522	8,050	5,828	—	44,199
,, ,, ...	3·50	14,476	9,888	15,778	9,660	6,956	—	56,758
,, ,, ...	6·0	17,633	8,496	8,418	9,800	6,862	12,444	51,209
,, ,, ...	7·0	18,711	8,448	13,846	9,590	6,533	12,308	57,128
,, ,, ...	8·0	14,938	8,400	15,962	6,720	7,379	10,624	53,399
,, ,, ...	11·0	18,865	6,720	16,192	4,690	7,943	10,880	54,410
,, ,, ...	12·0	22,253	14,640	stopped	stopped	8,789	8,500	54,182
	a.m.							
Wed., Oct. 6...	1·0	22,176	17,424	—	—	8,319	11,016	47,919
,, ,, .	6·15	23,331	17,280	—	—	9,964	9,248	50,575
,, ,, ...	8·0	21,142	18,048	—	—	9,212	8,908	48,402
,, ,, ...	9·0	22,330	15,264	—	—	9,400	8,568	46,984
,, ,, ..	10·0	23,331	14,880	—	—	9,776	9,248	47,987
,, ,, ...	11·0	23,331	15,696	—	—	8,742	10,336	47,769
	p.m.							
,, ,, ...	1·0	18,788	15,168	—	—	7,802	9,656	41,758
,, ,, ..	2·0	23,584	16,032	—	—	8,272	8,432	47,888
,, ,, ...	4·0	22,407	14,688	—	—	7,567	8,772	44,662
,, ,, ...	5·0	24,794	12,336	—	—	8,037	9,520	45,167
,, ,, ...	7·0	24,255	19,584	—	—	10,105	8,568	53,944
,, ,, ...	8·0	25,564	15,792	—	—	9,494	9,792	50,850
,, ,, ..	9·0	27,412	17,936	—	—	9,776	7,888	56,124
,, ,, ...	8·40	[1]	—	—	—	—	—	—
,, ,, ...	10·0	25,256	17,616	—	—	9,964	14,892	52,836
,, ,, ...	11·0	—	—	—	—	—	8,092	—
,, ,, ...	12·0	27,720	17,760	—	—	11,280	9,792	56,760
	a.m.							
Thur., Oct. 7...	1·0	28,336	19,392	—	—	13,165	10,268	60,893
,, ,, ...	3·0	28,875	17,000	—	—	11,139	9,928	57,014
,, ,, ...	4·0	28,182	17,184	—	—	10,763	10,404	56,129
,, ,, ...	6·0	29,260	18,336	—	—	9,682	11,696	57,278
,, ,, ...	7·0	28,105	17,136	—	—	11,186	9,316	56.427 [2]
,, ,, ...	8·0	27,027	17,520	—	—	10,669	8,432	55,216
,, ,, ...	9·0	25,564	14,016	—	—	10,340	9,452	49,920
,, ,, ...	10·0	23,177	14,448	—	—	9,870	7,480	47,495

1 Measurement, 9,964 cubic feet opposite the dip-side wheel on the west chain-haulage road.
2 Measurement at end of brattice, 5,364 cubic feet.

APPENDIX.—TABLE II.—RECORDING THE VOLUME OF AIR PER MINUTE VENTILATING THE VARIOUS DISTRICTS.

NOTE.—The records are given for only every 4 hours. The registrations were, however, made and given to the manager every hour during night and day.

Date, 1886.	Time.	Dip-side.	West Overcast.	Stables.	East Overcast.	New East.	West Door.	Brattice.	No. 1.	No. 6 Return.	West Return.	Total Volume of Air.
		Cubic Ft.	Cubic Ft.	Cub. Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.
Friday, November 19 ...	10·0 p.m.	6,204	35,328	5,845	8,568	17,568	10,890	3,654	—[1]	6,480	11,340	55,945
Saturday, November 20 ...	2·0 a.m.	4,982	30,720	2,940	8,136	19,728	11,660	3,234	—[1]	7,080	10,962	46,778
,, ,, ...	6·0 ,,	6,298	34,944	5,845	10,080	19,512	9,922	3,150	—[1]	6,840	9,009	57,167
,, ,, ...	10·0 ,,	5,234	35,072	5,040	11,448	18,792	11,308	3,780	1,520	8,400	11,308	57,294
Monday, November 22 ...	2·0 ,,	9,024	40,832	4,704	17,496	9,360	20,922	6,318	—	15,600	14,301	72,056[2]
,, ,, ...	6·0 ,,	8,977	41,984	5,308	18,288	13,824	22,044	5,418	5,200	14,640	14,679	74,557
,, ,, ...	10·0 ,,	9,870	40,576	4,242	21,816	13,320	20,108	4,788	4,880	14,280	14,490	76,504
,, ,, ...	2·0 p.m.	9,165	39,168	3,486	18,000	11,016	19,338	4,200	4,760	16,500	13,230	69,819
,, ,, ...	6·0 ,,	7,990	35,584	3,360	20,232	11,088	18,766	4,116	4,600	14,940	12,600	67,166[3]
,, ,, ...	10·0 ,,	6,721	36,096	3,108	18,720	10,368	18,854	3,444	3,960	12,060	12,285	64,645
Tuesday, November 23 ...	2·0 a.m.	7,097	37,120	3,066	11,952	7,992	15,840	3,696	4,920	9,420	11,403	59,235
,, ,, ...	6·0 ,,	8,366	35,456	3,402	20,232	11,376	18,480	2,142	5,680	13,260	12,600	67,456
,, ,, ...	10·0 ,,	7,661	36,096	2,940	17,928	10,584	17,292	3,318	5,280	12,660	11,781	64,625
,, ,, ...	2·0 p.m.	7,943	34,176	2,898	20,736	10,224	17,886	3,318	5,760	12,720	11,214	65,753
,, ,, ...	6·0 ,,	7,191	37,248	3,234	17,784	9,360	18,040	3,444	5,280	13,860	12,096	65,457
,, ,, ...	10·0 ,,	7,896	37,760	3,990	16,488	9,432	18,524	3,402	5,800	12,480	12,033	66,134
Wednesday, November 24	2·0 a.m.	8,037	38,400	4,158	21,024	12,096	18,524	2,142	5,200	12,300	12,096	71,619
,, ,, ...	6·0 ,,	7,520	32,896	2,772	14,760	8,856	16,544	2,436	5,200	12,120	11,088	57,948
,, ,, ...	10·0 ,,	7,238	32,128	1,974	16,920	8,424	19,008	2,814	4,040	11,460	10,143	58,260
,, ,, ...	2·0 p.m.	6,768	32,512	2,520	16,416	8,208	16,742	3,318	4,960	13,200	10,206	58,216
,, ,, ...	6·0 ,,	7,097	32,640	2,772	15,768	8,640	16,588	2,436	5,080	11,460	10,710	58,277
,, ,, ...	10·0 ,,	7,520	33,664	3,066	17,712	10,152	17,666	2,016	5,360	11,880	12,474	61,962
Thursday, November 25 ...	2·0 a.m.	7,426	34,816	3,150	15,840	7,632	17,732	2,562	5,040	14,340	11,466	61,232
,, ,, ...	6·0 ,,	9,024	38,144	2,898	20,232	8,712	18,590	2,436	5,560	12,840	12,222	70,298
,, ,, ...	10·0 ,,	7,896	36,480	2,562	18,936	9,216	18,414	4,032	5,640	14,880	13,860	65,874
,, ,, ...	2 0 p.m.	6,392	40,832	2,226	10,584	5,400	12,672	3,276	3,920	8,760	10,773	60,030[4]
,, ,, ...	6·0 ,,	9,259	40,448	3,654	20,448	10,512	17,402	5,082	6,920	14,400	12,411	73,809[5]
,, ,, ...	10·0 ,,	9,400	35,072	3,276	17,712	10,368	18,326	3,738	6,200	10,800	13,482	65,460

1. Not sufficient velocity to turn anemometer in No. 1 road. 2. Volume of ventilation after alteration was made. 3. No. 6 sheet being eased.
4. Fan running at 35 revolutions. 5. Fan running at 40 revolutions, sheets eased at east overcast, and partition-doors on east side.

APPENDIX.—TABLE III.—RECORDING THE VOLUME OF AIR PER MINUTE VENTILATING THE VARIOUS DISTRICTS.

NOTE.—The records are given for only every 4 hours. The registrations were, however, made and given to the manager every hour during night and day.

Date, 1886.	Time.	Dip-side.	West Overcast.	Stables.	East Overcast.	New East.	West Door.	Brattice.	No. 1.	No. 6 Return.	West Return	Total Volume of Air.
		Cubic Ft.	Cubic Ft.	Cub. Ft.	Cubic Ft.	Cubic Ft	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.
Friday, November 26 ...	2·0 a.m.	10,575	44,160	4,242	21,456	12,384	19,866	3,780	6,240	20,700	15,309	80,433
,, ,, ...	6·0 ,,	9,024	35,712	3,276	17,784	10,296	17,446	3,654	4,920	19,200	12,474	65,796
,, ,, ...	10·0 ,,	8,037	35,328	3,234	18,288	9,720	17,754	3,528	5,600	10,980	12,726	64,887
,, ,, ...	2·0 p.m.	8,460	36,864	3,234	21,096	10,728	18,502	3,780	6,320	19,200	13,419	69,654
,, ,, ...	6·0 ,,	7,755	38,860	3,738	19,728	10,944	18,370	3,528	6,080	17,160	12,663	68,085
,, ,, ...	11·50 ,,	11,374	30,976	3,948	15,408	10,080	5,232	4,746	9,200	—	—	61,706 [1]
Saturday, November 27 ...	6·0 a.m.	14,664	32,384	2,898	17,424	9,144	14,412	2,562	8,160	16,680	13,860	67,370 [2]
,, ,, ...	10·0 ,,	10,058	33,408	3,234	17,568	9,142	12,696	2,226	8,240	17,880	12,663	64,268
Monday, November 29 ...	10·0 ,,	9,682	30,592	3,570	18,936	10,152	13,881	11,424	7,640	12,660	17,136	62,780 [3]
,, ,, ...	2·0 p.m.	10,293	33,792	3,402	20,376	12,600	13,209	10,458	8,600	—	—	67,863
,, ,, ...	6·0 ,,	9,400	34,304	3,654	21,240	8,928	13,331	11,172	8,200	—	—	68,598
,, ,, ...	10·0 ,,	10,340	33,024	2,184	18,144	9,432	13,234	9,660	7,680	13,260	16,065	63,692
Tuesday, November 30 ...	2·0 a.m.	9,588	35,328	3,276	18,792	13,536	13,093	10,416	8,040	—	—	66,984
,, ,, ...	6·0 ,,	11,045	33,024	3,864	17,928	13,104	13,684	9,576	7,680	—	—	65,861
,, ,, ...	10·0 ,,	11,609	34,176	3,444	16,920	10,296	15,488	13,650	10,360	14,460	16,506	66,149
,, ,, ...	2·0 p.m.	10,576	34,176	4,158	19,440	11,016	14,674	12,684	10,560	—	—	68,349
,, ,, ...	6·0 ,,	12,267	35,968	4,536	18,936	11,880	15,972	13,104	11,680	—	—	71,707 [4]
,, ,, ...	10·0 ,,	12,220	37,376	3,990	20,952	12,960	16,104	12,222	11,040	15,420	18,648	74,538 [4]
Wednesday, December 1 ...	2·0 a.m.	12,502	34,176	2,688	19,800	12,380	12,768	10,416	9,920	—	—	69,166 [5]
,, ,, ...	6·0 ,,	13,536	32,000	3,864	16,920	11,448	12,336	10,626	10,720	—	—	66,320 [5]
,, ,, ...	10·0 ,,	13,254	37,888	4,494	17,568	10,440	12,684	11,718	11,400	—	—	73,204 [5]
,, ,, ...	2·0 p.m.	13,301	33,920	4,578	15,336	10,656	12,996	11,928	12,040	—	—	67,135 [5]
,, ,, ...	6·0 ,,	11,938	34,048	4,494	18,576	11,016	13,176	12,516	12,040	—	—	69,056 [5]
,, ,, ...	10·0 ,,	13,113	41,462	3,150	21,024	10,800	16,588	12,012	10,720	19,920	22,176	78,631 [6]
Thursday, December 2 ...	2·0 a.m.	13,348	42,752	4,536	19,368	13,392	18,656	12,474	11,800	—	—	80,004 [6]
,, ,, ...	6·0 ,,	12,784	39,424	4,326	19,792	10,368	17,820	12,852	12,120	—	—	76,326 [6]
,, ,, ...	10·0 ,,	13,677	41,856	5,334	22,968	12,384	16,698	16,254	12,760	—	—	83,835 [6]

1. West door partly covered, No. 6 undercast recovered, and No. 6 return sheet opened. 2. West door opened to 12 square feet in area, and No. 6 undercast opened. 3. No. 6 undercast recovered. 4. Fan running at 80 revolutions. 5. West door, 12 square feet in area. 6. Fan running at 60 revolutions; west door, 22 square feet in area.

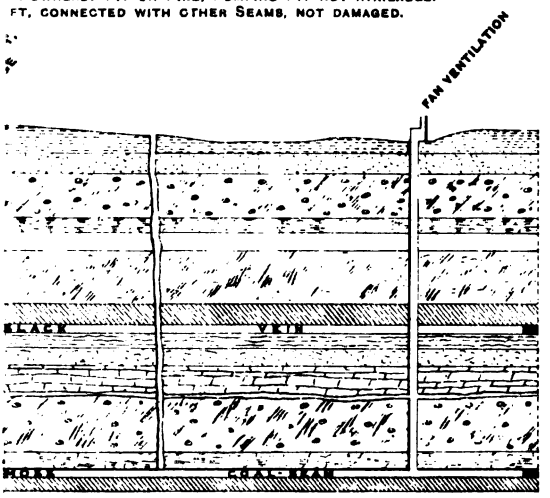
f Coal-mines after Explosions."

FIG. 2.

CASE No. 2.

INDICATIONS ON SURFACE.

DOWNCAST PIT ON FIRE, PUMPING PIT NOT AVAILABLE.
FT, CONNECTED WITH OTHER SEAMS, NOT DAMAGED.



JGGESTIONS FOR RECOVERY.

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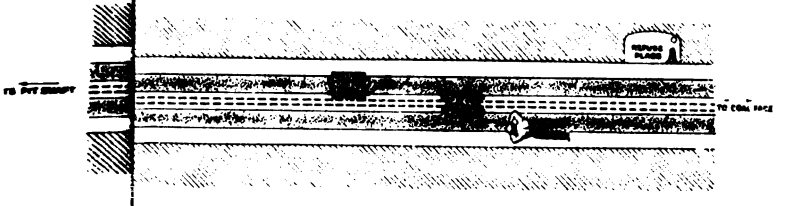
NOS. 22 TO 41, 43 TO 62, 64, 69 TO 71, AND 76.

NOS. 1, 2, AND 3.



ON BEFORE ANYTHING WAS DISTURBED.

And^w Reid & Comp^y L^td Newcastle on

APPENDIX.—TABLE III.—RECORDING THE VOLUME OF AIR PER MINUTE VENTILATING THE VARIOUS DISTRICTS.

NOTE.—The records are given for only every 4 hours. The registrations were, however, made and given to the manager every hour during night and day.

Date, 1886.	Time.	Dip-side.	West Overcast.	Stables.	East Overcast.	New East.	West Door.	Brattice.	No. 1.	No. 6 Return.	West Return	Total Volume of Air.
		Cubic Ft.	Cubic Ft.	Cub. Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.
Friday, November 26 ...	2·0 a.m.	10,575	44,160	4,242	21,456	12,384	19,866	3,780	6,240	20,700	15,309	80,433
,, ,, ...	6·0 ,,	9,024	35,712	3,276	17,784	10,296	17,446	3,654	4,920	19,200	12,474	65,796
,, ,, ...	10·0 ,,	8,037	35,328	3,234	18,288	9,720	17,754	3,528	5,600	10,980	12,726	64,887
,, ,, ...	2·0 p.m.	8,460	36,864	3,234	21,096	10,728	18,502	3,780	6,320	19,200	13,419	69,654
,, ,, ...	6·0 ,,	7,755	38,860	3,738	19,728	10,944	18,370	3,528	6,080	17,160	12,663	68,085
,, ,, ...	11·50 ,,	11,374	30,976	3,948	15,408	10,080	5,232	4,746	9,200	—	—	61,706 [1]
Saturday, November 27 ...	6·0 a.m.	14,664	32,384	2,898	17,424	9,144	14,412	2,562	8,160	16,680	13,860	67,370 [2]
,, ,, ...	10·0 ,,	10,038	33,408	3,234	17,568	9,142	12,696	2,226	8,240	17,880	12,663	64,268
Monday, November 29 ...	10·0 ,,	9,682	30,592	3,570	18,936	10,152	13,881	11,424	7,640	12,660	17,136	62,780 [3]
,, ,, ...	2·0 p.m.	10,293	33,792	3,402	20,376	12,600	13,209	10,458	8,600	—	—	67,863
,, ,, ...	6·0 ,,	9,400	34,304	3,654	21,240	8,928	13,331	11,172	8,200	—	—	68,598
,, ,, ...	10·0 ,,	10,340	33,024	2,184	18,144	9,432	13,234	9,660	7,680	13,260	16,065	63,692
Tuesday, November 30 ...	2·0 a.m.	9,588	35,328	3,276	18,792	13,536	13,093	10,416	8,040	—	—	66,984
,, ,, ...	6·0 ,,	11,045	33,024	3,864	17,928	13,104	13,684	9,576	7,680	—	—	65,861
,, ,, ...	10·0 ,,	11,609	34,176	3,444	16,920	10,296	15,488	13,650	10,360	14,460	16,506	66,149
,, ,, ...	2·0 p.m.	10,576	34,176	4,158	19,440	11,016	14,674	12,684	10,560	—	—	68,349
,, ,, ...	6·0 ,,	12,267	35,968	4,536	18,936	11,880	15,972	13,104	11,680	—	—	71,707 [4]
,, ,, ...	10·0 ,,	12,220	37,376	3,990	20,952	12,960	16,104	12,222	11,040	15,420	18,648	74,538 [4]
Wednesday, December 1 ...	2·0 a.m.	12,502	34,176	2,688	19,800	12,380	12,768	10,416	9,920	—	—	69,166 [5]
,, ,, ...	6·0 ,,	13,536	32,000	3,864	16,920	11,448	12,336	10,626	10,720	—	—	66,320 [5]
,, ,, ...	10·0 ,,	13,254	37,888	4,494	17,568	10,440	12,684	11,718	11,400	—	—	73,204 [5]
,, ,, ...	2·0 p.m.	13,301	33,920	4,578	15,336	10,656	12,996	11,928	12,040	—	—	67,135 [5]
,, ,, ...	6·0 ,,	11,938	34,048	4,494	18,576	11,016	13,176	12,516	12,040	—	—	69,056 [5]
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Thursday, December 2 ...	2·0 a.m.	13,348	42,752	4,536	19,368	13,392	18,656	12,474	11,800	—	—	80,004 [6]
,, ,, ...	6·0 ,,	12,784	39,424	4,326	19,792	10,368	17,820	12,852	12,120	—	—	76,326 [6]
,, ,, ...	10·0 ,,	13,677	41,856	5,334	22,968	12,384	16,698	16,254	12,760	—	—	83,835 [6]

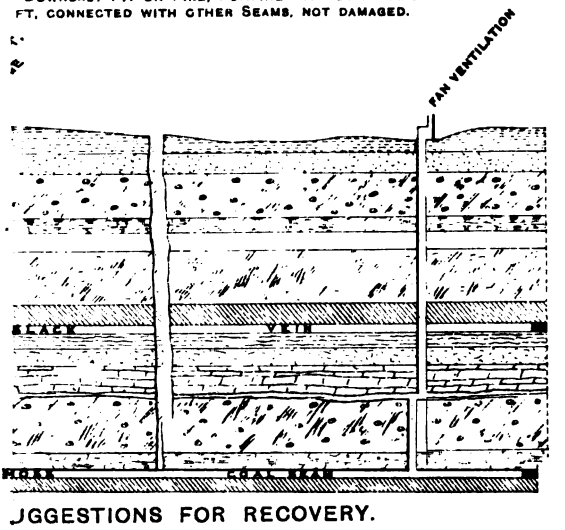
1. West door partly covered, No. 6 undercast recovered, and No. 6 return sheet opened. 2. West door opened to 12 square feet in area, and No. 6 undercast opened. 3. No. 6 undercast recovered. 4. Fan running at 50 revolutions. 5. West door, 12 square feet in area. 6. Fan running at 60 revolutions; west door, 22 square feet in area.

FIG. 2.

CASE No. 2.

INDICATIONS ON SURFACE.

DOWNCAST PIT ON FIRE, PUMPING PIT NOT AVAILABLE.
FT, CONNECTED WITH OTHER SEAMS, NOT DAMAGED.



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Nos. 22 to 41, 43 to 62, 64, 69 to 71, and 76.

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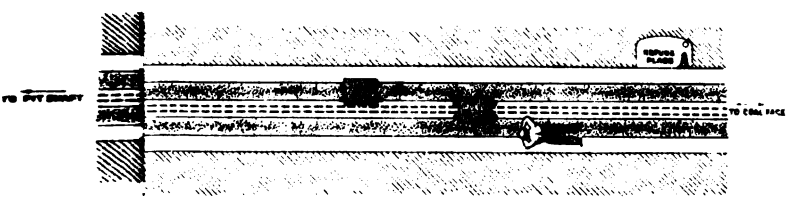
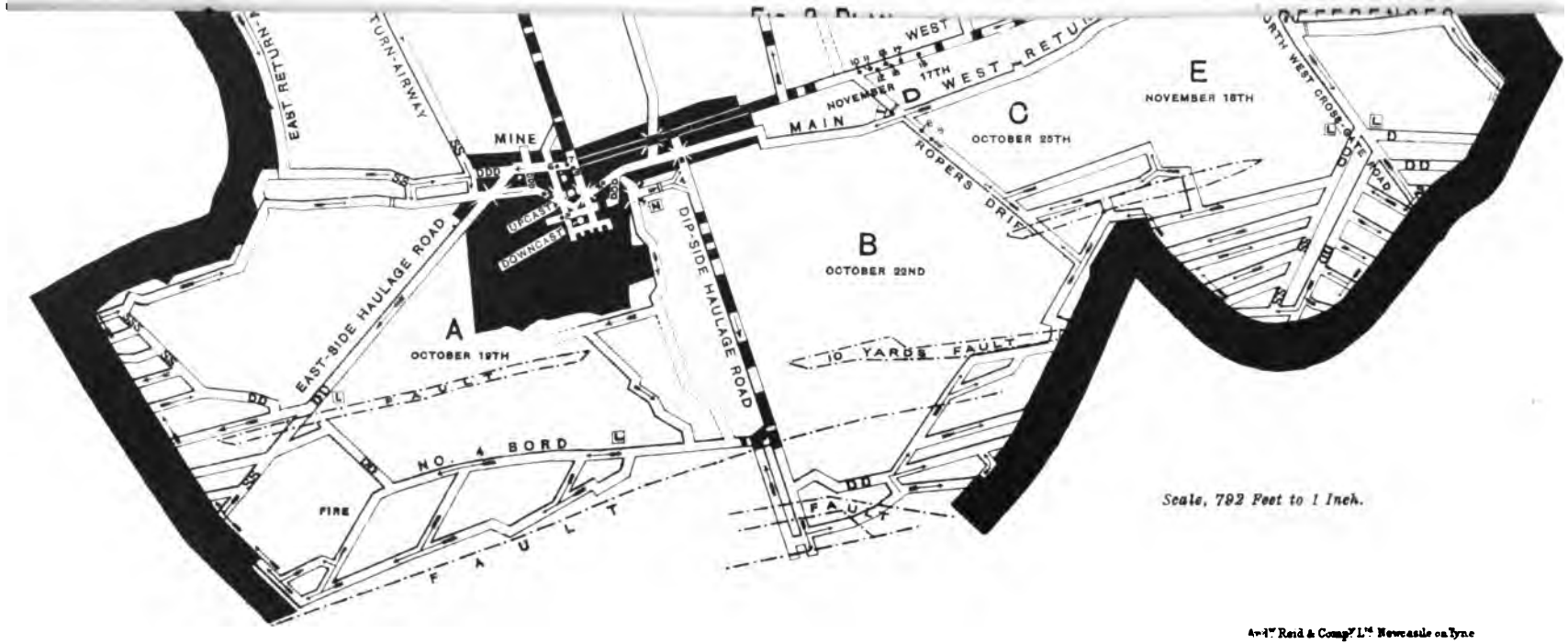


ON BEFORE ANYTHING WAS DISTURBED.

Ard^w Reid & Comp^y L^td Newcastle on Tyne

The Federated Institution of Mining Engineers.
Transactions 1895-7

To illustrate Mr. W. E. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions."



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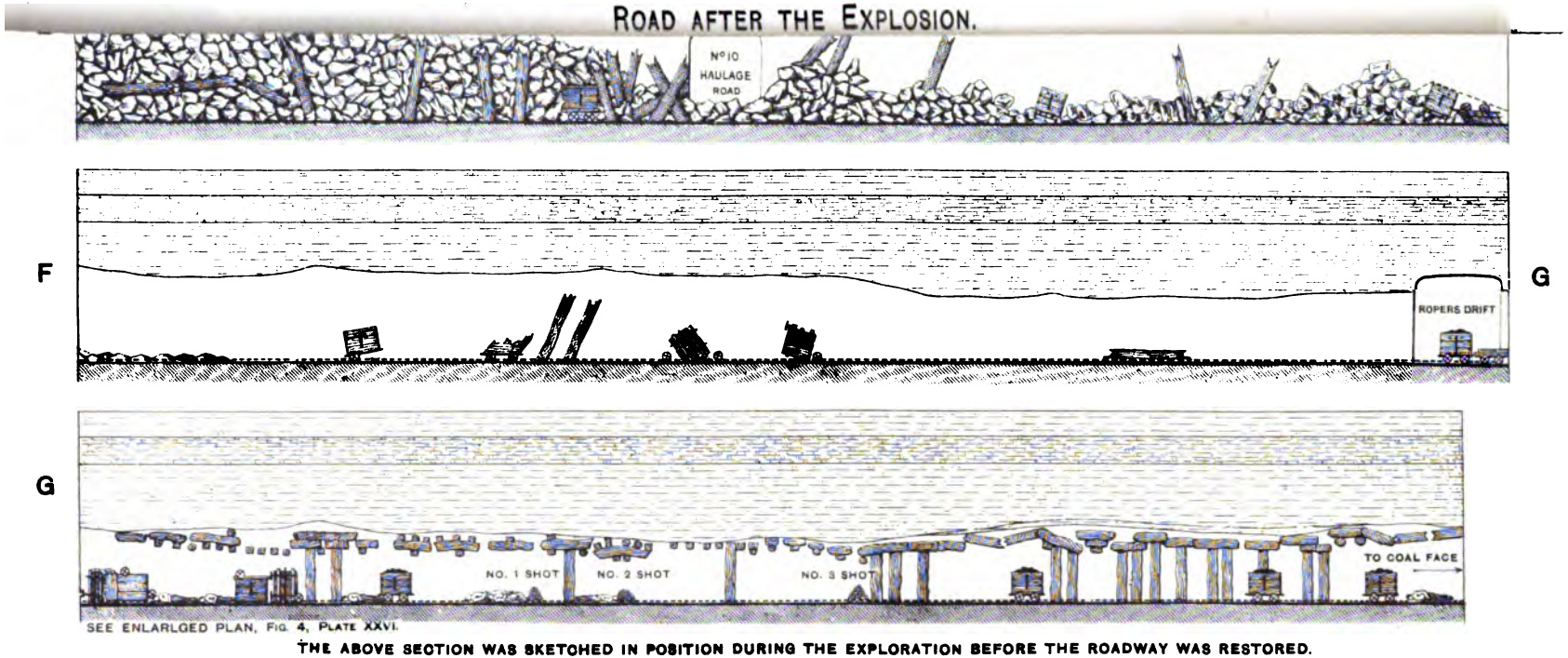
The Federated Institution of Mining Engineers
Transactions 1896 7

To illustrate Mr. W. E. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions."

FIG. 5.—LONGITUDINAL SECTION SHEWING THE STATE OF THE MAIN WEST CHAIN HAULAGE ROAD AFTER THE EXPLOSION.



SEE ENLARLGED PLAN, FIG. 4, PLATE XXVI.

THE ABOVE SECTION WAS SKETCHED IN POSITION DURING THE EXPLORATION BEFORE THE ROADWAY WAS RESTORED.

THE DISTANCE REPRESENTED BY THE ABOVE SKETCH IS 1,620 FEET.

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Transactions 1896-7

To illustrate Mr. W.E. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions."

FIG. 6. VENTILATION DIAGRAM.—TOTAL QUANTITY OF AIR.

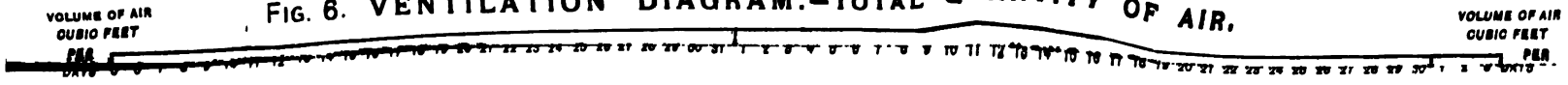
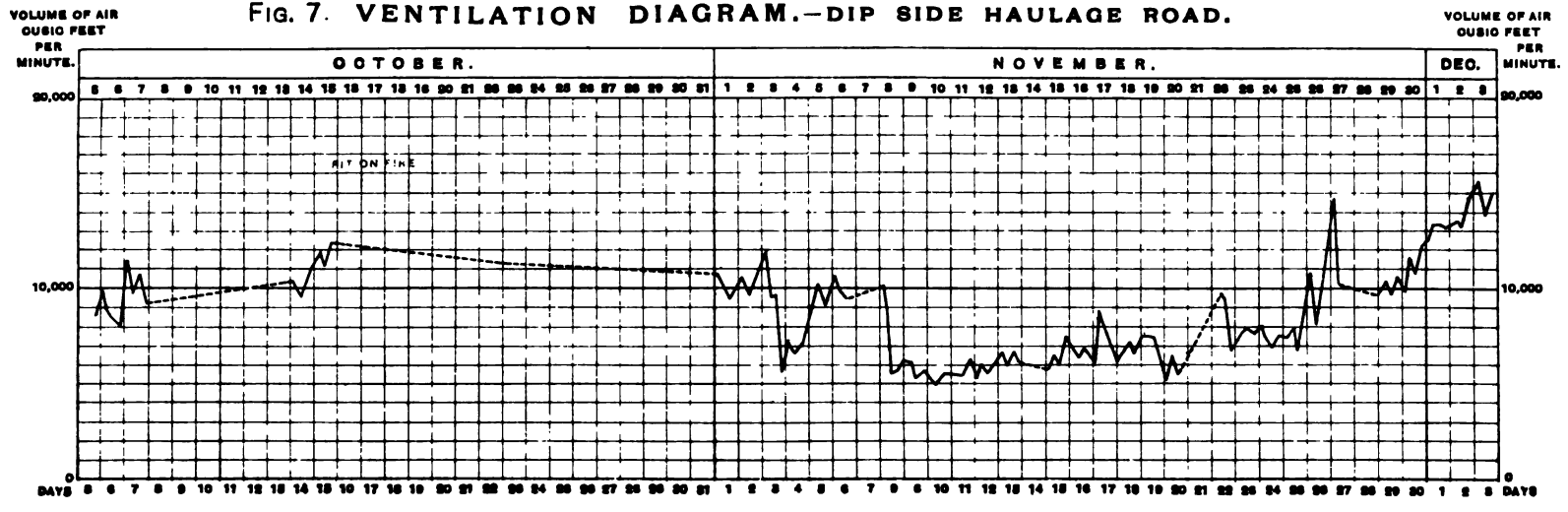


FIG. 7. VENTILATION DIAGRAM.—DIP SIDE HAULAGE ROAD.



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To illustrate Mr. W.E. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions."

FIG. 8 VENTILATION DIAGRAM.—WEST CHAIN-HAULAGE ROAD.

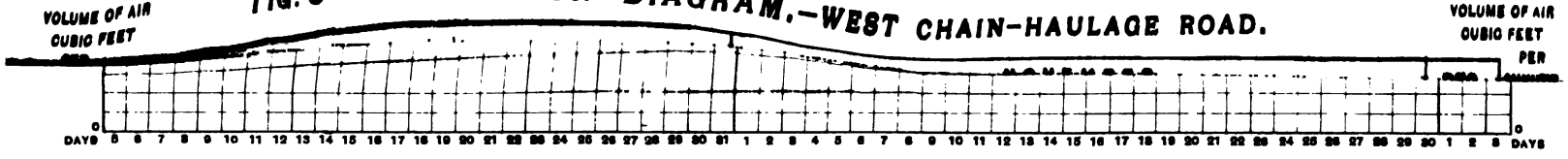
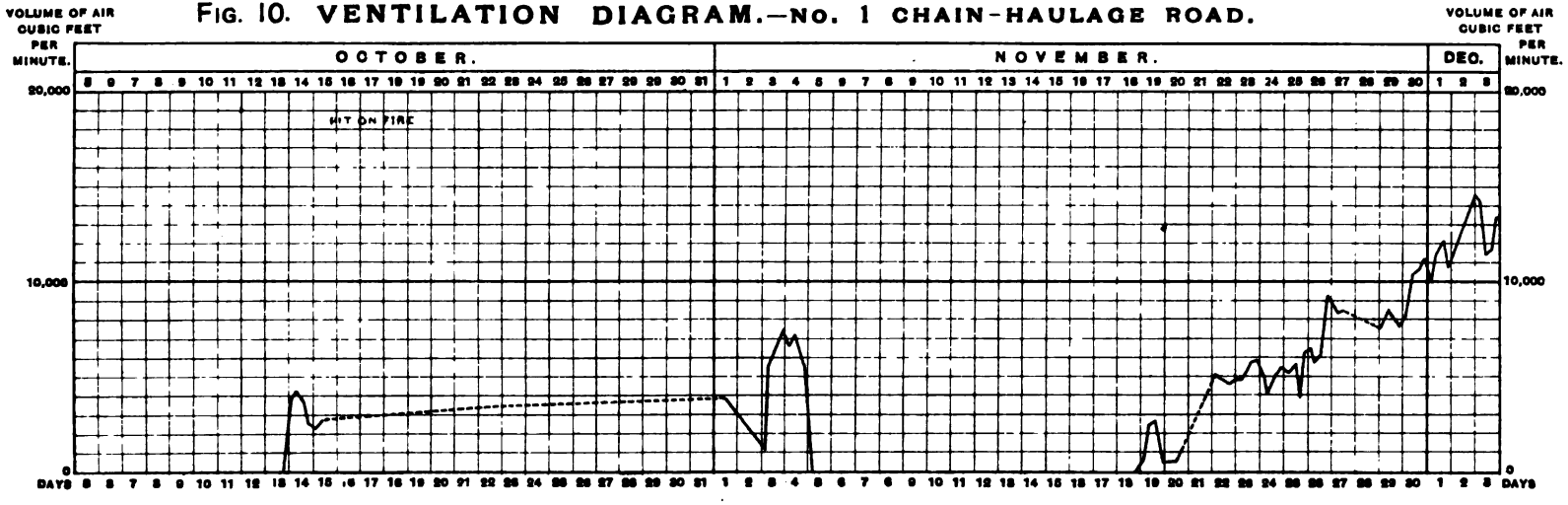


FIG. 10. VENTILATION DIAGRAM.—NO. 1 CHAIN-HAULAGE ROAD.



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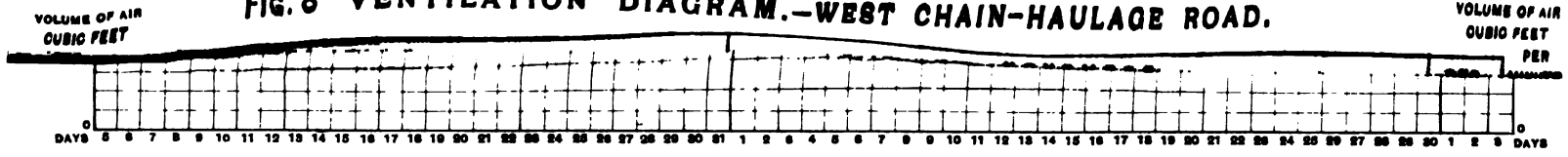

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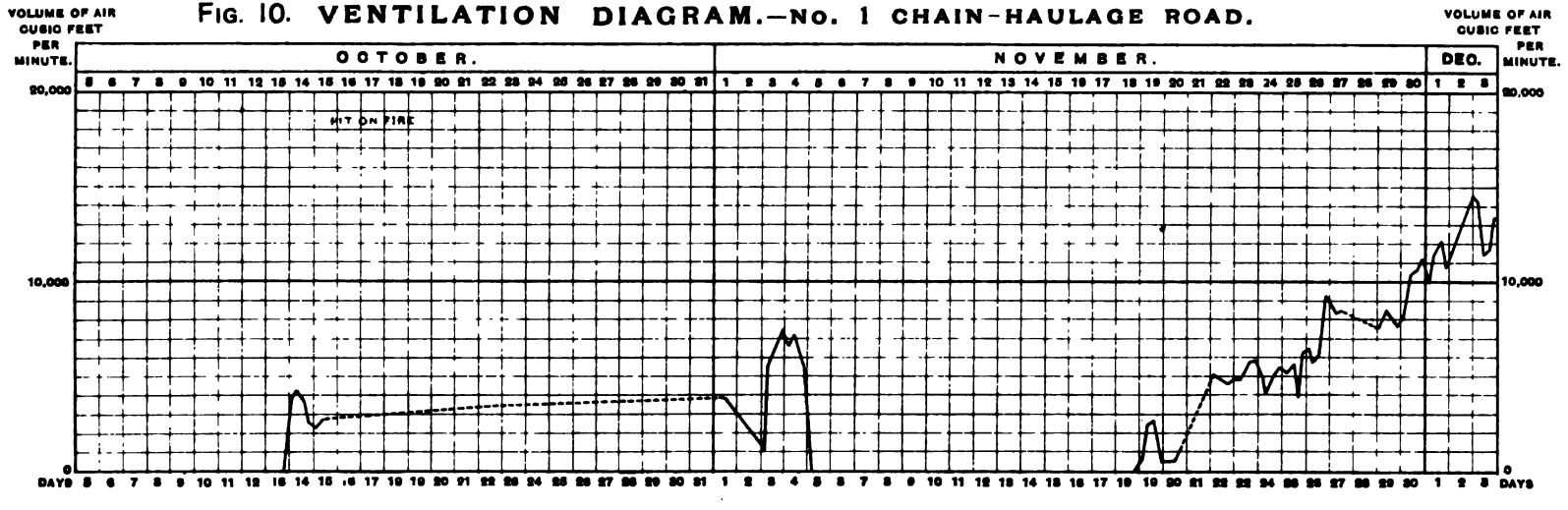

APPENDIX.—TABLE IV.—RECORDING THE VOLUME OF AIR PER MINUTE VENTILATING THE VARIOUS DISTRICTS.

NOTE.—The records are given for only every 4 hours. The registrations were, however, made and given to the manager every hour during night and day.

Date, 1886.	Time.	Dip-side.	West Overcast	Stables.	East Overcast.	New East.	West Door.	Brattice.	No. 1.	No. 6 Return.	West Return.	Total Volume of Air.
		Cubic Ft	Cubic Ft.	Cub. Ft	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.	Cubic Ft.
Thursday, December 2 ...	2·0 p.m.	13,301	42,240	2,940	22,752	4,104	23,095	20,664	13,480	—	—	81,233 [1]
,, ,, ...	6·0 ,,	14,100	43,008	3,066	22,536	5,688	22,242	20,202	14,000	—	—	82,710 [2]
,, ,, ...	10·0 ,,	14,758	39,168	3,402	20,088	7,344	21,153	19,992	14,560	19,920	25,704	77,416 [3]
Friday, December 3 ...	2·0 a.m.	15,510	44,800	2,394	21,024	6,408	20,262	17,850	14,320	—	—	83,728 [3]
,, ,, ...	6·0 ,,	13,912	43,392	3,234	21,240	7,128	21,972	19,320	14,800	—	—	81,778 [3]
,, ,, ...	10·0 ,,	13,912	41,472	3,864	20,592	3,406	22,274	22,050	11,200	—	—	79,840 [3]
,, ,, ...	2·0 p.m.	15,040	37,760	—	22,248	5,106	20,831	21,294	11,440	—	—	75,048 [4]
,, ,, ...	10·0 ,,	12,220	45,440	1,470	18,792	3,406	20,498	17,766	13,240	—	—	77,922
Saturday, December 4 ...	2·0 a.m.	13,912	38,784	—	17,854	4,218	20,165	17,640	13,720	—	—	70,552 [5]
,, ,, ...	6·0 ,,	14,382	39,424	1,105	19,080	5,032	19,351	16,884	13,840	—	—	74,991 [6]
,, ,, ...	2·0 p.m.	13,865	35,200	910	17,568	10,804	20,979	18,398	12,200	—	—	67,543
,, ,, ...	6·0 ,,	14,523	39,168	2,184	18,436	6,734	22,200	20,496	13,800	—	—	74,311 [7]

1. West door, 31 square feet in area. 2. West door, 33 square feet in area. 3. West door, 37 square feet in area. 4. New east door, 74 square feet in area, and sheet in No. 1. 5. Fan running at 59 revolutions; stables, 13 square feet in area. 6. Door set in Ropers drift, and sheet in west chain-haulage road beyond No. 20 gate. 7. Fan running at 70 revolutions.

The PRESIDENT said that the members were indebted to Mr. Garforth for his paper, which was of great interest, and likely to prove very useful. The rules would be valuable to mining engineers in advising them what to do in the event of an accident occurring.

Mr. R. ROUTLEDGE (Garforth) wrote that Mr. Garforth's paper contained very good suggestions or precautions to be taken previous to an explosion. At the Micklefield colliery explosion, one cage of the downcast shaft was in the sump and the other was smashed and suspended among the timbers of the head-gear. The bottom of the upcast pit was partly closed by the compressed-air pipes (9 inches in diameter) being broken and twisted across the shaft. After a lot of work and risk, they managed to reach the upcast pit-bottom in about 1½ hours. It was fully 12 hours before the one cage was got to work in the downcast shaft. Had the cages in the upcast shaft suffered to the same extent, 33 of the workmen who were saved would have been in misery 12 hours longer, for want of a winding capstan. With respect to No. 7 precaution, he suggested that a speaking-tube in the shaft would be better than a hammer-and-cord signal. In lieu of a small reserve fan, as suggested in Nos. 10 and 11 precautions, he (Mr. Routledge) recommended that a steam-jet should be fixed half-way down the upcast shaft. A steam-jet was fixed in the upcast shaft at the Garforth collieries, and if, at any time, the fan broke down or had to stop for the engine to be changed, the workman went to the boiler and turned the steam on to the jet in the shaft. He (Mr. Routledge) could also commend the use of a waterfall for cooling the air and sweeping the after-damp out after an explosion. At Micklefield colliery, timber was thrown, by the force of the explosive blast, from the head-gear a distance of 400 feet and broke the steam-pipes conveying the steam to the fan, and it was 12 hours before the fan resumed work. He was quite satisfied that a waterfall would have produced a useful current of air, which could have been used in the exploration of the mine, where the overcast air-crossing had not been destroyed.

Mr. W. COCHRANE (Newcastle-upon-Tyne) said that Mr. Garforth's paper brought before the members, as object lessons, a great number of considerations, which no doubt would be impressed upon the minds of mining engineers. Many members who read the precautions to be taken before an accident, if they would compare that list with what they might have in their minds, would find themselves deficient. Some engineers postponed the matter and thought that there would be ample time when the accident happened, but if they read this paper they would

perhaps not be satisfied without adopting many of the precautions recommended. For instance, few collieries had an ambulance corps.

Mr. HENRY HALL (H.M. inspector of mines) thought that Mr. Garforth's object might be carried out very conveniently if the examiners of candidates for managers' certificates were to include such questions in the examinations. It might also be possible for some of the rules to be included in the Special Rules of the colliery.

Mr. JOHN GERRARD (H.M. inspector of mines) thought that it was a very bold move on the part of Mr. Garforth to put on record the facts connected with such a serious explosion as that with which he had had to deal. It was not every mining engineer who would care to subject himself to criticism and possibly attack, but Mr. Garforth had considered his subject for many years, and he was to be congratulated on the complete way in which he had done his work. This record of his experience in connexion with explosions would prove very valuable for future reference, and more especially should his paper be consulted before the occurrence of an explosion, in order that the various appliances and remedies might be at hand. The rules might perhaps be open to criticism on account of their length. One of the advantages of having a code of rules was that they might be easily and readily referred to, and, perhaps, a revised code could be drawn up from Mr. Garforth's exhaustive code, which could be placed in every mining office for constant reference by the officials.

In making these few remarks, he sought to support Mr. Garforth in the necessity for these precautions, and he did not intend to criticize or discuss the many interesting points which that gentleman had brought before them. He had very recently seen for himself the great service of some of the remedies advocated. He should not have believed that compressed oxygen could be of such great service in connexion with explorations after explosions as it had proved to be in a recent case.

The PRESIDENT, in moving a vote of thanks to Mr. Garforth for his paper, said that the proposed rules would prove very useful to managers, owners of mines, and also to the workmen.

Mr. GARFORTH briefly acknowledged the vote of thanks.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, FEBRUARY 12TH, 1898.

MR. GEO. MAY, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 29th and that day.

The following gentlemen were elected, having been previously nominated :—

HONORARY MEMBER—

Sir CHARLES MARK PALMER, Bart., M.P., Grinkle Park, Loftus, R.S.O.

MEMBERS—

Mr. THOMAS L. BATES, Government Inspector of Collieries, Hamilton, Newcastle, New South Wales.

Mr. WILLIAM CHARLTON, Mining Engineer, Guisborough, Yorkshire.

Mr. JAMES FAILSHAW COOK, Mechanical Engineer, Washington Ironworks, Washington, Co. Durham.

Mr. JOHN DIXON, Senior Government Inspector of Collieries, Merewether, Newcastle, New South Wales.

Mr. C. FERGUSON, Colliery Manager, Walbottle Colliery, Newcastle-upon-Tyne.

Mr. ARTHUR DARLING NICHOLSON, H.M. Inspector of Mines, 14, Chatsworth Square, Carlisle.

Mr. ALBERT JOHN ALFRED ORCHARD, Mining Engineer and Manager of Nailstone Colliery, near Leicester.

Mr. WILLIAM THOMAS REES, Mining Engineer, Maesyffynon, Aberdare, South Wales.

Mr. JOHN J. SANDEMAN, Mining Engineer, 17, Berners Street, London, W.

Mr. DAVID CURLE SMITH, Mechanical and Electrical Engineer, Little Sylvester Street, Coolgardie, Western Australia.

Mr. JOHN JAMES TURNBULL, General Manager, East Indian Coal Company, Limited, Jherryia P.O., District Manbhoom, Bengal, India.

Mr. JOHN VAUGHAN, Mechanical Engineer, Balaclava House, Dowlais, South Wales.

Mr. PHILIP GALBRAITH WATSON, Colliery Manager, Blaydon Burn Colliery, Blaydon-upon-Tyne.

ASSOCIATE MEMBERS—

Mr. HERBERT AINSWORTH, P.O. Box 1,553, Johannesburg, Transvaal.
Mr. CHARLES JOHN BANKS, Westwood, Washington, R.S.O., Co. Durham.
Mr. VICTOR M. BRASCHI, Bajos de Portacoeli No. 11, Ciudad de Mexico, Mexico.
Mr. HENRY HOLLIDAY, Consett Iron Company, Limited, Blackhill.
Mr. EDMUND GEORGE LAMB, Old Lodge, Salisbury.
Mr. STEPHEN E. LAMB, 6, Charles Street, Berkeley Square, London, W.
Mr. DAVID H. LAWRANCE, c/o R. S. Cunningham & Co., 91, Cannon Street, London, E.C.
Mr. P. W. D. PICKUP, Rishton Colliery, Rishton, near Blackburn.
Mr. THOMAS SAMPY, Stockton Colliery, Newcastle, New South Wales.
Mr. D. W. A. SAUNDERS, Worcester Chambers, Swansea.
Mr. SAMUEL STEWART, 16, Great George Street, Westminster, London, S.W., and Parkhurst, Park Road, Wallington, Surrey.
Mr. TREVOR F. THOMAS, Llandaff Place, Cardiff.
Mr. E. A. WEINBERG, Queensland Smelting Company, Limited, Aldershot, Maryborough, Queensland, Australia.
Mr. JOHN WELFORD, Tighes Hill, Newcastle, New South Wales.

ASSOCIATES—

Mr. JOHN CARROLL, Deputy-overman, East Hedley Hope Colliery, Tow Law, R.S.O., Co. Durham.
Mr. JAMES E. DAVIS, Assistant Manager and Surveyor, South Medomsley Colliery, Dipton, R.S.O., Co. Durham.
Mr. F. DAVISON, Middle-shift-overman, 58, Hedley Hill Terrace, Waterhouses, Co. Durham.
Mr. MATHEW DAVISON, Back-overman, Hedley Hill Colliery, Waterhouses, Co. Durham.
Mr. WILLIAM HALL, Under-manager, Elswick Collieries, Newcastle-upon-Tyne.
Mr. ALEXANDER HAMPSON, Under-manager, St. Helen's Colliery, Bishop Auckland.
Mr. GEORGE HARE, Under-manager and Surveyor, Seghill Colliery, Northumberland.
Mr. DEMSTER HORNSBY, Assistant Under-manager, Murton Colliery, *via* Sunderland.
Mr. JAMES NICHOLSON HUGHES, Under-manager, Hedley Hill Colliery, Waterhouses, Co. Durham.
Mr. ROBERT KELLETT, Overman, Littletown, near Durham.
Mr. WILLIAM LITTLE, Deputy-overman, Linton Colliery, Morpeth.
Mr. JOHN MARSHALL, Under-manager, Cheetham Lane, Swinton, near Manchester.
Mr. WILLIAM ROWLAND OWEN, Miner, 32, Duke Street, Millom, Cumberland.

STUDENTS—

Mr. W. S. BARWICK, Mining Student, 713, Burrard Street, Vancouver, British Columbia.
Mr. WILLIAM B. COXON, Mining Student, Langley Park Colliery, Durham.
Mr. GLANVILLE REAH, Mining Student, Newlands, Gosforth, Newcastle-upon-Tyne.
Mr. ARTHUR JOHN WALTON, Mining Student, Seghill Colliery, Northumberland.

AWARDS FOR PAPERS.

The SECRETARY read the following list of papers communicated during the year 1896-97, for which prizes of books had been awarded by the Council to the authors :—

"The Gold-fields of the Hauraki Peninsula, New Zealand." By the Rev. Joseph Campbell.
"Cornish Methods of Mine Timbering." By Mr. G. P. Chaplin.
"The Mineral Resources of the Colony of Queensland." By Mr. William Fryar.
"Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant." By Mr. W. T. Hallimond.
"Notes upon Foreign Mining Laws, and Adequate Areas for Mining Concessions." By Mr. H. D. Hoskold.
"The Education of Metallurgists." By Mr. Saville Shaw.
"Notes on the Sinking of Two Shafts at Claravale Colliery." By Mr. F. R. Simpson.

DISCUSSION ON MR. FRANK REED'S PAPER ON "HYDROTHERMAL GOLD-DEPOSITS AT PEAK HILL, WESTERN AUSTRALIA."*

Prof. H. LOUIS was doubtful whether the title of the paper conveyed the writer's meaning. The view he (Prof. Louis) held in common with most mining geologists of the present day was that all primary gold-deposits were hydrothermal deposits, and therefore to particularly describe this deposit as such was equivalent to speaking of coal-beds as of a vegetable origin. It would be of interest to know whether the writer used "hydrothermal" in this meaning, or whether he meant to describe the deposit as a geyserian deposit—a favourite explanation by Australian geologists of the origin of gold-deposits, *e.g.*, Mount Morgan, in Queensland. The author might also be asked to explain the phrase "thermal crater"—the ordinary definition of this term would be "a crater caused by heat"—did the writer mean a crater caused by volcanic action or by a geyser?

The following paper by Mr. Walter Merivale was read on the "Occurrences and Mining of Manjak in Barbados, West Indies" :—

* *Trans. Fed. Inst.*, vol. xiv., page 89.

OCCURRENCES AND MINING OF MANJAK IN BARBADOS, WEST INDIES.

By WALTER MERIVALE, Memb. Inst. C.E., Memb. Inst. M.M.E., etc.

Manjak is the local name for an asphalt. It is one of the many bitumens that the modern demand for insulating-material, varnishes, waterproofs, etc., has called into the market. Manjak is of two kinds, distinguished by buyers as the Emtage and the Merivale manjak, from the names of the producers. The first is fully equal to the second for certain purposes, but it cannot be so effectively used in the higher priced manufactures, for which the Merivale quality is in demand.

The meaning of the word *manjak* is obscure. Sir Robert Schomburgk, in his *History of Barbados*, quotes a reference to it in an old book of voyages, where it is called *mountjack*, but that name seems to throw little light on the origin of the word. Barbados was never the property of any European nation but the British, and manjak is purely a local term, so that the meaning of the word must be sought in the English language, unless it can be traced back to the Caribs.

About 6 or 8 years ago, the then manager of the Barbados railway tried to turn manjak to account as a fuel by compressing it into blocks, after mixing it with various substances. His efforts were not successful, and, when the author succeeded him as manager of the railway, the use of manjak as a fuel had long been abandoned. No other use for it was known, and all interest in the mineral had faded away. Mr. C. J. Greenidge, however, had sent samples to New York, and it was these samples, probably, that attracted an enterprising gentleman, Mr. Pinny, to the island, who, arriving when the author had been here about a year, represented to him that he was part proprietor in a fuel company in Boston, which owned large tracts of peat, and that he desired to acquire all the asphalt-deposits of Mexico, Venezuela, and the West Indies. The author's attention being thus directed towards manjak as a source of traffic for the railway, he took some pains to look into the matter, with the result that he found that the mineral occurred in the Scotland district in pockets, apparently in no great number and of no great size, and in a manner difficult of identification. There did not appear to be much traffic for the railway in this product. But the question how

the pockets came to be where they were could not be dismissed hurriedly. Consideration of the subject suggested that the mineral found in pockets must have been broken off a main body, and the frequent occurrence of landslips in the Scotland district, where they were found, supported this theory. Later, a vein was pointed out in another district, where the ground was not disturbed by slips. This vein showed strong indications of having been thrust upwards from below.

Once satisfied that manjak occurring in pockets was an accident, and that it originally appeared in veins, it was not difficult to perceive a very strong probability that the veins were merely indications of a much larger mass below, and that in fact they all proceeded from one and the same source; and, further, that the source of the Barbados manjak might very possibly be also the source of its relative the Trinidad lake-pitch. Some corroboration of the theory that the Barbados veins were connected was afforded later by the fact that they generally strike north-north-west. (The veins of gilsonite in the Vinta Reserve, U.S.A., strike in the same direction. Has this any connexion with the earth-crinkle which forms the axis of Northern and Central America?)

The author now began experiments to ascertain whether after all this mass of combustible could not be used for fuel on the railways, and in sugar-making. It soon became apparent that the right method of burning it was to take advantage of its extreme friability, grind it into fine dust, and inject it into the furnace with a jet of steam. This system was applied with success to a locomotive, a steam-launch and a shop-engine boiler, but it was difficult to introduce it among the sugar-factories on account of the initial expense (£20) of putting up the apparatus. Dusting the powder on to the megas, or crushed canes, however found favour amongst the planters quickly, and a business was also begun with small bricks of lime and manjak-dust made into mortar and allowed to set. The author still uses these bricks at the mines, but the supply of refuse is too small to admit of their being sold. After some months' trial of manjak as a fuel on the railway, the author decided to abandon it for several reasons, one of which was that a market had been discovered for the mineral, which sent the price up 100 per cent.

Before proceeding to describe the manner of mining for manjak, it will be well to say a few words about the geology of Barbados.

Barbados is a coral-island, one of the few, if not the only one, that can boast of exhibiting seven distinct periods of elevation in seven distinct terraces of coral. The earliest geological history of Barbados is

found in the Scotland shingles or sandstones, which from their coarseness denote their deposition in shallow water. Above them comes a deposit of oceanic ooze, consisting both of radiolarian and of infusorial earth, which is taken to indicate that the Scotland formation sank to a depth of 6,000 to 12,000 feet at a time when there was a connexion between the Pacific and the Atlantic Oceans. The evidence on this point is found by Messrs. Jukes-Browne and Harrison in the fact that radiolarian earth has been found in the Pacific Ocean, but not in the Atlantic Ocean, and that both radiolarian and infusorial earths occur in the oceanic deposits of Barbados. Without denying the accuracy of their conclusions, it may be worth noting that the fact that radiolarian earth has not yet been found in the Atlantic Ocean is not a proof that it does not exist there.

The Scotland shingles now began to rise again, bringing with them the oceanic deposit, on which, as they rose, the coral organisms built and died until the island reached its present form.

The Scotland formation contains also a blue clay,* sometimes interstratified with the sandstone—as in the Emtage pit at Bissex Hill—at other times below it, and, in the Conset district, where the Merivale mines are situated, there is no sandstone, but the blue clay underlies marl, calcareous sandstone and infusorial earth. It looks as if the blue clay had been deposited before the sandstone, which would mean a period of depression anterior to the deposition of the Scotland shingles. On this point, the author's mind is not clear, but it is certain that the blue clay is the lowest formation in which he has yet found manjak, and he believes that the blue clay has not yet been pierced in any part of the island.†

Messrs. Jukes-Browne and Harrison, in their pamphlet on the geology of Barbados, speak of bitumen and of petroleum occurring in a certain formation above the blue clay. These writers do not seem to have perceived that the source of these minerals was very much farther down than any borings have yet reached—unless we take into account those of the new West India Oil Syndicate. Manjak they were content to regard as an isolated deposit occurring here and there. The truth appears to be that there is beneath the island an enormous reservoir of liquid bitumen which is still trying to force its way to the surface. In the Conset district, there is a

* The blue clay contains 30 per cent. of iron, and the blue colour is said to be due to its presence.

† The author has been informed by an old resident, since this paper was written, that the blue clay was pierced by a well which he had dug, and that very hard rock was found below it.

hill, or rather a piece of the cliff, about 300 feet long, on the coast, called Burnt Hill, which is described by them as being impregnated with bitumen. Impregnated it certainly has been, but the impregnation took place very many feet below the level it at present occupies, and before it was thrust up through the calcareous sandstones and marls. These still stand on either side of it in alternate strata, from 3 to 12 inches thick, exposed on the face of the cliff, and rapidly and more rapidly inclined upwards as they near the intruded mass of shale. The shale, moreover, shows no stratification, but is simply a huge mass. The author has sunk shafts on both sides of it and found it below the marl. This shale, or bituminous clay, has the following analysis :—*

Moisture	7·52
Ash	76·19
Carbon	14·32
Hydrogen (not included in moisture)	1·05
Oxygen, etc.	0·92

As the shaft increased in depth thin veins of hard manjak were found, and others of liquid manjak, and of semi-liquid manjak. In the Conset district, the coral-capping has been removed, and the manjak exposed in more than one spot.

When met with, some way below the surface, the blue clay is soft and treacherous, the fissures, which divide it up into a million blocks, contain bitumen or water, and the blocks slide from their places as soon as the miner's pick removes the supporting rock or manjak from before them. Higher up, the blue clay seems to be almost a different formation, and is as hard as rock, not unlike chalk, and crossed and recrossed by thin streaks of manjak and of gypsum. Large quantities of iron pyrites are also found here and there in it, in nodules and in very thin veins.

The manjak-veins are thrust up through all the formations except the coral, which probably indicates that the intrusion occurred before the coral was formed, or it may mean that it occurred after it was formed, but was unable to get through it. In the latter case, however, the ends of the veins would be flattened out against the bottom of the coral, instead of ending in thin streaks in the softer lower formation.

The rain having washed away this lower formation after the removal of the coral-cap, the thin outcrop is exposed, and at times a stream, cutting its way down a hillside, carves out a piece of the vein that crosses its path, leaving exposed a section of the vein on each side of the gully; or the waves eat away the cliffs, and exhibit the cross-section of a vein running out to sea.

* The author, by a crude distillation, produced 30 gallons of oil per ton shale.

It was upon one of these stream-exposed veins that the author began work just 2 years ago, and it is from this vein or pocket, as the geologists are understood still to call it, that he has extracted over 2,000 tons. In it can still be shown indications as favourable as those which caused the writer to commence operations. Want of capital forced him to hew wherever the vein was wide enough when the mine was first started, but now that matters are more settled a better method is being adopted in his new mines.

In sinking a shaft for coal, the engineer must prepare for the passage of several hundred tons a day, but with manjak a hundred tons a week is sufficient for the market, so that a shaft that is wide enough for pumping, ventilation, and the slow passage of buckets is all that is required.

In the Merivale mines, the standard type-shaft has been fixed at 8 feet by 6 feet, divided across its greater length into three divisions, a small one for the ladder-way, and two larger ones for pumps and buckets. The two buckets, which measure 26 inches in diameter by 2 feet deep, occupy the central division which is divided by boards into two equal tubes, and the pumps are placed in the end division. The southern and the western sides of the shaft are continued upwards by boarding for a height of 10 feet, where is the stage on which rests the crab, and where later on will be the large pulley-wheels. The division between the pumps and the buckets is continued by boards also up to this staging, and is carried down to within 10 feet of the bottom of the shaft. The prevailing wind being from the north-east, it blows down the bucket-division and up through the pumping-division, or, if it shifts to the south-east, the direction of the air-current is reversed. Should the current blow from the east a door can be closed on the pumping side. But, as a matter of fact, the wind seldom varies more than a point or two from north-east, and if it varies too far, or drops altogether, the mere division down the shaft is sufficient to set up some ventilation.

In sinking a shaft through hard bituminous clay (shale ?), it is found that one man can hoist in one ascending and one descending bucket, of the dimensions just given, as much as two men and a boy can dig and fill below, in a shaft 8 feet by 6 feet, down to a depth of 50 feet. The cost is 4s. a yard exclusive of water and timbering. The timber used down to that depth is pitch-pine joists 6 inches by 6 inches, with 1 inch spruce-boards for lagging, the pitch-pine frames are placed 5 feet apart, and have 4 inches b[illegible] al struts between them at the corners. It must be reme[illegible] visions in the shaft mentioned above prevent any tim[illegible] n of over 3

when, after spending all their money, they have discovered that they had been working on a broken-off pocket. That the island is rich in manjak seems now to be demonstrated, but the main body has not been met with at 300 feet from the surface, and the author is of opinion that it may not be met with within ten times that distance, but that the first man who gets to it will make a fortune. It is not by any means impossible that this main body is still fluid, a huge underground pitch lake.

The following are analyses of Merivale manjak and of Trinidad glance-pitch :—

	Merivale Manjak.	Trinidad Glance-pitch.
Specific gravity	1·123	1·139
Melting point	420° Fahr.	360° Fahr.
Matter soluble in carbon bi-sulphide	97 per cent.	88 per cent.
Ash	2·32 ,,	7·44 ,,
Ash, colour	reddish	greyish.
Loss on heating	2·61 per cent.	9·4 per cent., after heating to 500° Fahr. for 2 hours.
Iodine absorption	42·2 ,,	42·0 per cent.
Organic dust	0·68 ,,	4·56 ,,

The PRESIDENT (Mr. George May) remarked that there would be a certain amount of danger in working the bitumen, especially if the galleries were further extended, as the dust from the manjak would fall and would be easily ignited.

Prof. H. LOUIS said that some few years ago there was a serious explosion from grahamite, which was a similar substance.*

Mr. T. Y. GREENER remarked that the floating dust would be a danger to the workmen's eyes. In the filling of pitch at the Peases West Bankfoot tarworks the men were very often incapacitated, owing to the effect of the dust upon their eyes, and it was necessary for them to wear close spectacles.

Mr. W. COCHRANE asked what was the average width of the vein of manjak, and whether it was found in large masses, or whether it was interspersed with rock which had to be broken up before the manjak was obtained. He also asked whether the pockets referred to in the paper were connected by veins with other pockets.

* *Trans. Fed. Inst.*, vol. x., page 560.

Prof. H. LOUIS suggested that information might also be given as to the direction of dip, and a section of the ground in which manjak was found. He knew of some similar substances, such as gilsonite, grahamite, albertite, and stellarite, the latter of which was worked in Nova Scotia, and there was a whole series of bitumens known in different parts of the world, which occurred in pockets or bunches or veinlets. Bitumen was found in the Mountain Limestone of Derbyshire, and he had seen bitumen-mining on a fairly large scale in some parts of Eastern Russia, where the mines were being worked in beds of Lower Carboniferous age. It occurred as a hard mass in streaks, pockets and veins, in certain definite horizons, as though the bitumen in a plastic state had filled up all the cracks and fissures. He would like to know the writer's reason for thinking that manjak came from a large internal deposit.

The PRESIDENT moved that a vote of thanks be accorded to Mr. Merivale for his interesting paper, and this was unanimously agreed to.

DISCUSSION ON MR. R. F. PERCY'S PAPER ON "THE DETERMINATION OF, AND USE OF, THE MAGNETIC MERIDIAN IN MINE-SURVEYING."*

Mr. G. C. HOOPER (Klerksdorp, Transvaal) wrote that although Mr. Percy's method of fixing on a magnetic base from which to proceed with a mine-survey (surface or underground) was an improvement on the common method of choosing any two points, such as junctions of fences, shafts, etc., it was not an absolutely reliable method, because, in addition to the points being incorrectly surveyed and plotted, there was also the liability of error due to local magnetic attraction. This latter source of error was more prevalent in metalliferous than in coal-mining districts, and might be seen and measured by staking out a straight line and reading its magnetic bearing at different points. The variations shown in Mr. Percy's paper† were probably due to local attraction, and there was, consequently, no certainty that the mean bearing of 67° 57′ 0″ was more nearly correct than the bearing *A*, *C* or *D*. In laying down the meridians on the plan as described by Mr. Percy, there was always a variation or difference in them, and the difficulty was to know which to adopt (the average being known to be incorrect). If all the work in connexion with the process was made with equal care it could not be argued that any one of them, or

* *Trans. Fed. Inst.*, vol. xii., page 581. † *Ibid.*, page 583.

the average bearing, was more nearly correct than another. Possibly this error might be small, but to it must be added errors due to incorrect surveying and plotting, expansion and contraction of plans, impossibility of close reading of an ordinary compass, and of directing the instrument exactly in the line of the points at each magnetic bearing read. These notes also referred to the method of obtaining a base-line by reading the magnetic bearings of one or more of the surface-survey lines, and he (Mr. Hooper) could see no difference between this method and that described by Mr. Percy. A survey carefully made with the magnetic needle might be very nearly correct, and if made in relation to some lasting surface-object or based on the true north line was useful for future reference. For extracting the due quantity of minerals on boundaries, however, and for use in determining a base for the survey, the needle was not sufficiently accurate, and should be discarded. Although an accurate survey cost more than a rough survey, it was apparent, and was generally conceded that the accurate survey was the preferable one, and this was chiefly due to the fact that both lives and money were frequently lost where incorrect and imperfect plans were used. It was the unfortunate fact that the danger and loss was not immediate that favoured the production of inaccurate plans. The average surveyor was incapable of making an accurate survey, and never would be able to correctly determine the true north line, nor to certify that his plans were correct. For these reasons, he (Mr. Hooper) thought that it would be worth the Government's consideration to make the trigonometrical points of the Ordnance Survey available for use, and issue to applicants the calculated co-ordinates of these points. The principal advantages resulting from this information would be that the most delicate and difficult part of the survey would be made by competent surveyors; that all surveys would originate in the true north line as determined by the Ordnance Surveyors; and that the carefully measured base-lines of the Ordnance Survey would be available for use (by calculating the distance between two suitable trigonometrical points from the co-ordinates). If the mine-surveys were made with proper instruments, further advantages were:—All stations of surface and underground surveys, and consequently the details of both, could be referred to the zero point of the Ordnance co-ordinates; the surveys could be conveniently recorded in a book kept for the purpose; future accidents and damage to property would be reduced; and there would be no excuse for inaccurate plans.

Mr. R. F. PERCY wrote that he had also occasionally found differences in magnetic readings at different points in the same line,

and had, in consequence, adopted the theodolite-dial method of comparison to detect and avoid misleading bearings. The method was intended for revision of old meridians, rather than for application to new plans, and would be found of service as a means of verifying surface-details. He admitted that Mr. Hooper's objection to taking the mean of several figures was not unfounded, but in averaging, he only followed the common practice of scientific observers. Perhaps it would be wiser to reject the bearing D, as it clearly differed from A, B and C, and was probably not normal, and thus increase the mean to 67° 58′; but he thought that a question of 0° 1′ in the direction of an ever-swinging line was of no moment, and he did not mean to imply that any magnetic survey could give precise and accurate results. Referring to the remarks on the Ordnance stations, if the information were supplied, the longitude above ground might be calculated, but the problem of transferring it to a deep mine would still remain unsolved.

DISCUSSION ON MR. HALLIMOND'S "NOTES ON THE COAL-SEAMS OF THE TRANSVAAL."*

Mr. W. T. Hallimond, in reply to Mr. Frank Simon's remarks, wrote that he did not state that "duff was useless," but that as yet there was no demand for it. The small coal obtained from some of the more bituminous seams, in the Middelburg district, coked fairly well, but would give a still greater percentage of good coke if properly treated by crushing and washing. He did not claim that the Rand collieries' appliances effected a saving of 1s. per ton over any "well-equipped" colliery in the Transvaal. He said that "the combined saving amounts to 1s. per ton over the old systems of banking out and bagging." Both Brakpan and the Cassell collieries had the old modes of banking out and bagging in use at the time of his paper being written. The shoots for bagging coal at the Rand collieries were different from those at other collieries, inasmuch as the coal after falling over the end of the picking-belt found its way by gravitation into the bags, whereas by the old system at the Brakpan and the Cassell collieries, the coal, after leaving a jigging perforated plate, accumulated in a large heap on a flat tray, from which it had to be shovelled by hand into the bags. There were no "new features" in the method of dumping at the Rand collieries, but he would suggest to any colliery manager putting up new plant, that elevating to the top of dump-heap level, by bucket-elevators, would

* *Trans. Fed. Inst.*, vol. xiii., page 372; and vol. xiv., page 131.

be more economical than hauling trucks up to that level by either animal or mechanical power. He could not compare costs with the Cassell or other colliery as he had no others in his possession, but he had every opportunity of comparing the old and new methods of banking-out, screening, sorting, and bagging.

DISCUSSION ON MR. H. D. HOSKOLD'S "NOTES UPON FOREIGN MINING LAWS AND ADEQUATE AREA FOR MINING CONCESSIONS."*

Mr. H. D. HOSKOLD wrote that an error had been discovered in the fourth line of paragraph three, from the bottom of page 171. The 10 years existing in that line was intended to read 1 year, as was exhibited in the descriptive heading of column 9, in Table IV. The figures at the place and page indicated should read as follows:—

"Also, 4,800·000000 × 1 year ÷ 0·052093 ounces per cubic metre = 92,142·898277 metres, or the length required under the conditions for a concession, with a width of 1 metre; but as the auriferous deposit is estimated at 2 metres in thickness, we also have 92,142·898277 ÷ 2 = 46,071·4491385 metres in length for the auriferous mining concession."

Further, in Figs. 1 and 2 (Plate VII.), the words "lengths in varas" should be taken to read "depths in varas," and in Fig. 3 (Plate VII.) the words "lengths in metres" should read "depths in metres," for the reason that in each case these lines are perpendicular to the surface or horizontal line, and consequently would represent the variable depths of shafts required to intersect the mineral veins at the deep boundary-line of each concession, the mineral vein or veins in which are found under the scale of inclined angles assigned.

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* *Trans. Fed. Inst.*, vol. xiii., page 160.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
FEBRUARY 12TH, 1898.

MR. H. D. COWAN IN THE CHAIR.

DISCUSSION ON MR. T. E. PARRINGTON'S PAPER ON "ECONOMICAL COMBUSTION OF COAL FOR STEAM-RAISING PURPOSES."*

Mr. T. E. PARRINGTON agreed with Mr. R. R. Simpson that the percentage of ash in the coal was somewhat large, but the results were those of an analysis of Busty coal from the Durham district. He did not think that Mr. Simpson had fully understood that the paper was intended to show that the "usual" was not always the "correct" allowance of air, and although 18 to 24 lbs. of air per pound of coal would no doubt usually be admitted he did not think that the results would be so good as with 15 to 20 lbs., according to the method of firing. With a mechanical stoker 15 lbs. of air should be an ample supply, and when firing by hand this quantity of air would be increased in the inverse proportion to the capabilities of the firemen, and the carbon-dioxide test would show their qualities or defects. The heat lost in maintaining the water in a state of vapour was more than counterbalanced by the heat created by the combustion of sulphur, and as both were small quantities they were both omitted. The selling price of 6s. per ton of coal was taken as a fair average value, and if the coal were more valuable the saving would be greater, and vice versâ as the writer had not intended the paper to apply only to collieries. He (Mr. Parrington) had previously considered the extra labour entailed by the use of an extra ton or [illegible] would be required. At Wearmouth Colliery [illegible] 1 boy could easily manage 4 Lancashire boilers [illegible] portion of labour was 3 men to 4 boilers and [illegible] just double the amount used per boiler at Wearmouth. [illegible]

* *Trans. Inst. Eng.*, vol. xiii. page 164.

Wearmouth colliery had shown an average evaporation of 9 lbs. of water per lb. of coal, and although he had not any figures for the other range of boilers, he considered that he was fairly safe in stating that they could not equal, much less excel, the results at Wearmouth colliery. He agreed with Mr. Simpson's last remark, that "by doubling the steam-pressure the same amount of energy can be developed by using only one half of the fuel." The owners of Wearmouth colliery were preparing to work their engines at a pressure of 120 lbs. per square inch at the Hylton winning.

The CHAIRMAN stated that at Elswick colliery a number of egg-ended boilers had been replaced by Lancashire boilers, and during the first year the cost of the new boilers had been repaid out of the value of the decreased quantity of coal consumed.

DISCUSSION ON MR. J. CADMAN'S "NOTES ON REARER WORKINGS."*

Mr. R. R. SIMPSON enquired whether any attempt had been made to work the Hams and Rough Seven Feet coal-seams when they were separated by 12 feet of rock. Could Mr. Cadman give any reason for the spontaneous combustion which seemed to occur so frequently in the North Staffordshire coal-mining district?

Mr. JOHN CADMAN said that of the two seams mentioned by Mr. Simpson, the bottom seam (Hams) was usually worked first, and the other or what could be got of it afterwards. The Rough Seven Feet seam was superior to the Hams, and it sometimes happened that the Hams coal was not worked. Spontaneous combustion (in the Bullhurst seam) usually occurred in districts where there was a rider coal or bituminous shale (hussel) underneath the seam, containing finely divided pyrites, and also highly oxidizable bituminous matter, and it was therefore probable that this shale was an important agent in the production of spontaneous combustion.

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* *Trans. Fed. Inst.*, vol. xiv., page 392.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS; AND MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

JOINT MEETING,
HELD IN THE ROOMS OF THE LITERARY AND PHILOSOPHICAL SOCIETY, SHEFFIELD, FEBRUARY 5TH, 1898.

MR. G. BLAKE WALKER, IN THE CHAIR.

The following gentlemen were elected members of the Midland Institute of Mining, Civil and Mechanical Engineers, having been previously nominated:—

MEMBERS—

Mr. FRED. DUTTON, Electrical Engineer, The Green, Heckmondwike.

Mr. WALTER FREDERICK JONES, Electrical Engineer, 25, Albert Street, Eccles, Manchester.

Mr. ALEXANDER MARR, Electrical Engineer, 66, Upper Brook Street, Manchester.

Mr. CECIL WALTON, Engineer, The Hardy Patent Pick Company, Limited, Sheffield.

The following gentlemen were elected to the Chesterfield and Midland Counties Institution of Engineers:—

MEMBER—

Mr. WALTER JABEZ BAKER, Mining Engineer, Byron Chambers, Market Place, Nottingham.

ASSOCIATE—

Mr. THOMAS TURNER MAWSON, Mining Student, Pemberton Colliery, near Wigan.

STUDENT—

Mr. WILLIAM JAMES LODGE, Mechanical Engineering Student, No. 1 Colliery, Hucknall Torkard.

Mr. T. G. LEES read the following paper on "Explosions in Air-compressors and Receivers":—

EXPLOSIONS IN AIR-COMPRESSORS AND RECEIVERS.

By T. G. LEES.

Previous to the explosion, which took place at the air-compressor and air-receiver, at Clifton colliery, on May 28th, 1897, an ignition occurred in one of the air-cylinders, without causing an explosion, on November 25th, 1895; and other similar explosions and ignitions have taken place, one at Ryhope colliery* and another at Newbattle colliery.† Mr. W. N. Atkinson, H.M. inspector of mines, also mentioned an explosion in a compressed air-receiver, which occurred at the Carn Bora mine in Cornwall, on August 16th, 1885. An explosion in an air-compressing cylinder is recorded by Mr. C. C. Ellison of the Wharncliffe Silkstone colliery, Barnsley. Other explosions and ignitions may have taken place in this country, but the writer has not been able to find any recorded beyond those above mentioned. In America and on the Continent, where compressed air is very extensively used for many purposes other than haulage-power, a number of explosions and ignitions have happened.

A plan and sectional elevation of the air-compressors and receivers at Clifton colliery, with the pipes communicating therewith, is shown in Figs. 1 and 2 (Plate XXXI.). There are two steam-cylinders, each 30 inches in diameter, the air-cylinders are 30 inches in diameter with 4 feet stroke, and were erected in 1877. The air-cylinders A, A^1 are in a line with the steam-cylinders, the piston-rods being coupled together. The inlet-valves M of the air-cylinders are hinged inside the cylinder-covers, one at each end, measure $11\frac{1}{4}$ inches by 7 inches, and are regulated in opening and closing by spiral springs. The discharge-valves K are placed on the top stem of the cylinders near to each end, measure $16\frac{3}{8}$ inches by 8 inches, and are specially constructed with the view of giving relief in raising the valve against the pressure in the air-receiver at the end of the stroke. The air-cylinders are provided with tanks or water-jackets, supplied with a continuous flow of cold water for cooling purposes; and these were arranged up to the time of the explosion so as to allow of the water overflowing at the level marked H, H^1 (Fig. 3, Plate XXXI.).

* *Trans. N.E. Inst.*, vol. xxxvii., page 197. † *Ibid.*, vol. xxxviii., page 3.

The air, on leaving the compressing cylinders, passes through the air-passages E and pipes B to the receivers C, C^1 and C^2, all of which are connected by pipes 8 inches in diameter, and thence from the receiver C by the pipe D to the shaft. The receiver C, nearest the engine-house, is 40 feet long, 7 feet in diameter, and fitted with two safety-valves. The receivers C^1 and C^2 are 40 feet long, 5 feet in diameter, and have one safety-valve each, weighted to blow off at a pressure of 60 lbs. per square inch.

Ignition and Explosion at Clifton Colliery.—The ignition occurred in the right hand air-cylinder on November 25th, 1895. There was no explosion in the air-receiver. The engineman saw a stream of sparks issuing from the inlet-valve M at the front end of the cylinder, and through the pipe-joints between the cylinder and the air-receiver. He noticed, at the same time, that the outlet-valve K at the same end of the cylinder had stuck and was not lifting. All the joints of the pipes were injured, and were re-made, but no further damage was discovered.

It was thought that the discharge-valve K, failing to lift, the hot compressed air in the cylinder was re-compressed for several strokes before the engine could be stopped, and by that means a very high temperature of the air was produced, so high as to volatilize the lubricating oil, and then to cause the ignition of the oil-vapour.

The explosion took place on May 28th, 1897. The pits commenced work at 7 a.m., the air-compressing engine running at the usual speed of from 40 to 48 revolutions per minute, and everything appeared to be in working order up to 8·45 a.m., when the engineman was startled by the safety-valves on the air-receivers suddenly blowing off with a deafening roar, the noise of which increased every second, and caused great alarm in the pit-yard. Flames several feet high were seen issuing at great pressure from the safety-valves, and sparks were blown out at the joints of the pipes leading from the discharge-valves of the air-cylinders to the air-receiver C. As soon as the engines were stopped, it was observed that the plates of the receiver C were heated to a very high temperature, and that the pipe D, carrying the air from the receiver to the pit, was nearly red-hot near to the receiver. The engineman, having left the engine-house, was not able to say anything as to the pressure indicated on the air-gauge. It was probable, as the hauling-engines in the pit kept on running for some minutes after the first alarm, and after the air-compressors were stopped, that this helped somewhat, in addition

to the relief obtained from the four safety-valves, to keep the pressure from attaining such proportions as to burst the air-receivers, or to do such other damage as occurred on similar occasions at other collieries.

The fact that something unusual had happened was soon noticed in the pit, as the fumes given off by the incandescent matter in the air-receiver were carried down the shaft to the hauling-engines. The effect of the gases exhausted from the engines caused great alarm to the workpeople, and rendered one of the engine-attendants partially unconscious. The smell of the fumes was disagreeable and pungent, and was noticed for some considerable distance from the pit-bottom, so that the men in the nearest district, about ½ mile inbye, put out their candles and came to the pit-bottom to ascertain the cause. The flames issuing from the safety-valves gradually subsided, and very shortly ceased; and, as soon as practicable, the safety-valves were eased, and the lids on the manholes were taken off to allow the receivers to cool down, water being thrown in for the same purpose, and to clear out any remaining gases, so that an examination could be made of the interior. A lighted safety-lamp was lowered into the receiver nearest to the engine-house soon after the lids were taken off, and it was immediately extinguished. This experiment was repeated at intervals until the receivers were clear of fumes and fit to be entered. Unfortunately, samples of the gases in the receivers were not obtained at the time, so that an analysis cannot be given. After the receivers had cooled down sufficiently to enable an inspection to be made of the interior it was found that on the bottom of receiver C, immediately under where the air first entered from the compressors, a deposit of black carbonaceous matter had formed, from 1½ to 2 inches thick, and 6 square feet in area, and a thin coating was noticed on the sides, but only at the end of the receiver nearest the inlet-pipe. This deposit was charred, and presented the appearance of hard vulcanite. The two receivers, C^1 and C^2, were free from deposit. The pipes B leading from the air-cylinders also contained a thin black deposit, more or less burnt. The air-cylinders and pistons were examined, and although signs of heating were apparent, the surfaces were not dry; the discharge-valves and passages E were coated with deposit about ¼ inch thick in the worst parts, which had evidently been incandescent but not quite consumed, some of it being of the consistency of stiff putty. Further examinations failed to detect any damage to the plant, but work was stopped for the day, and the men were drawn out of the pit.

The conditions likely to cause the explosion would be (1) a much higher temperature than the theoretical temperature of the compressed air due to the working pressure; (2) a comparatively low temperature of the flashing and ignition points of the oil used for lubricating the piston and air-cylinder; and (3) supplying a larger quantity of oil than could be used up in the lubrication, and so leaving a surplus in the cylinders and in the outlet valve-chests and air-pipes.

About 20 years ago, a thermometer was fixed on the outlet air-pipe *B*, as near to the discharge-valves as practicable, to indicate the temperature of the compressed air (Fig. 3, Plate XXXI.). The thermometer scale was graduated to read up to 500° Fahr., and the temperature usually registered was about 350° Fahr.; but on one occasion the mercury rose above 500° Fahr., and the tube was burst. At the time of the explosion no thermometer was in use, and the temperature of the compressed air was not known. After the explosion, a pyrometer was fixed at the same point as stated above, and the temperature was found to range from 400° to 420° Fahr., varying with the speed of the engine and the pressure of the air as shown in Table I. The air-compressing cylinders were also indicated, and the results are also comprised in Table I.

TABLE I.

No. of Experiment.	Revolutions per Minute.	Maximum Indicated Pressure in Air-cylinder.	Pressure in Air-receiver.	Excess of Pressure.	Temperature of Compressed Air.	Temperature of Engine-house.	Temperature of Water at Overflow.
		RIGHT HAND AIR-CYLINDER.					
		Lbs. per Square Inch.	Lbs. per Square Inch.	Lbs. per Square Inch.	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.
1	48	62	50	12	420	80	116
2	48	66	51	15	400	80	116
3	24	67	60	7	405	80	116
4	40	78	61	17	400	80	122
		LEFT HAND AIR-CYLINDER.					
5	24	71	60	11	420	83	104
6	40	75	61	14	420	81	128
7	48	59	42	17	410	81	128
8	44	74	55	19	420	83	104

NOTE.—The temperature outside the engine-house was 60° Fahr.

From statements recorded in Table I., it will be noticed that the pressure of the air in the cylinders at the end of the stroke exceeded that in the air-receiver, as shown on the air-pressure gauge, by 19 lbs. per square inch as a maximum, and 7 lbs. per square inch as a minimum. The

difference in pressure between 19 and 7 lbs. is probably due to the varying speeds of the engines, being low when the speed was slow and increasing generally with the speed, and the slight deviation from this rule probably arose from some difference in the action of the discharge-valves. Generally speaking, when the air-compressor was running at a high speed the increased pressure indicated suggested that for such speeds the area of the discharge-valves was insufficient to allow of the air, at its increased velocity, escaping freely at the end of the stroke. The discharge-valves are oblong in form, and hinged, made of gun-metal, the difference of area on the upper and under sides being due to the seating; the area being smaller on the under side, adds to the pressure required in lifting the valves to overcome the resistance from the pressure in the air-receiver and pipes. The dimensions and areas are as follows:—Upper side, 17 inches by 3·56 inches, or 60·52 square inches; under side, 16·37 inches by 3 inches, or 49·11 square inches. If we take No. 1 experiment, with the pressure of the air in the receiver at 50 lbs. per square inch, then the pressure due to lifting of the discharge-valve would be (60·52 × 50 ÷ 49·11 =) 62 lbs. per square inch, which agreed with the indicated pressure, and showed that a pressure of 12 lbs. per square inch was required to lift the discharge-valves. Where the pressure required to lift the discharge-valve is more or less than that due to the difference of the areas of the upper and lower side of the discharge-valve, it may probably be owing to the difference in the speed of the engine and to some slight difference in the working of the discharge-valve.

Referring to the temperatures of the compressed air recorded in Table I., the theoretical temperature of the air, when compressed along the adiabatic curve or a pressure-curve corresponding to any alteration of volume, and assuming that heat is neither gained nor lost during compression, is given by the formula:— $\frac{t_1}{t} = \left(\frac{p_1}{p}\right)^{\frac{\gamma-1}{\gamma}}$, in which t represents the given absolute temperature in degrees Fahrenheit; p the absolute pressure of air in pounds per square inch; t_1, p_1 the absolute temperature in degrees Fahrenheit, and absolute pressure in pounds per square inch of the same quantity of air under changed conditions; and $\gamma = 1{\cdot}408$ constant. For instance, what should be the temperature of the air with an initial temperature of 80° Fahr., when compressed to a pressure of 78 lbs. per square inch, as shown in No. 4 experiment? In this case p is 14·70 lbs. per square inch above a vacuum; p_1, 92·70 lbs. per square inch above a vacuum, or 78 lbs. of indicated pressure; t, the

absolute temperature of the air, when its initial temperature is 80° Fahr., is (80° + 460° =) 540° Fahr. at the pressure p; γ, 1·408; $\frac{\gamma - 1}{\gamma}$, 0·29; and t_1, the absolute temperature of the air compressed to 92·70 lbs. per square inch is found, by the preceding equation, to be 461·13° Fahr., showing an increase of temperature during compression of 381·13° Fahr. The temperature registered is practically 61° Fahr. less than the theoretical temperature, showing that the air during compression had been slightly cooled. If the initial temperature of the air when entering the cylinder had been 50° instead of 80° Fahr., the theoretical temperature due to the same pressure as in No. 4 experiment would be 409·96° Fahr., or 51·17° less than for the initial temperature of 80° Fahr., showing the advantage to be gained by admitting the air into the cylinder at as low an initial temperature as possible.

Table II. is taken from a reprint of a lecture on *Compressed-air Production* delivered at Sibley College, Cornell University, U.S.A., by Mr. William Saunders. The temperatures shown in column 5 are calculated by the preceding formula from an initial temperature of 60° Fahr.

TABLE II.—HEAT PRODUCED BY COMPRESSION OF AIR.

Pressure.			Volume.	Temperature of the Air Throughout the Process.	Total Increase of Temperature.
In Atmospheres.	Above a Vacuum.	Above the Atmosphere or Gauge-pressure.			
	Lbs. per Sq. In.	Lbs. per Sq. In.	Cubic Feet.	Degrees Fahr.	Degrees Fahr.
1·00	14·70	0·00	1·000	60·0	00·0
1·10	16·17	1·47	0·9346	74·6	14·6
1·25	18·37	3·67	0·8536	94·8	34·8
1·50	22·05	7·35	0·7501	124·9	64·9
1·75	25·81	11·11	0·6724	151·6	91·6
2·00	29·40	14·70	0·6117	175·8	115·8
2·50	36·70	22·00	0·5221	218·3	158·3
3·00	44·10	29·40	0·4588	255·1	195·1
3·50	51·40	36·70	0·4113	287·8	227·8
4·00	58·80	44·10	0·3741	317·4	257·4
5·00	73·50	58·80	0·3194	369·4	309·4
6·00	88·20	73·50	0·2806	414·5	354·5
7·00	102·90	88·20	0·2516	454·5	394·5
8·00	117·60	102·90	0·2288	490·6	430·6
9·00	132·30	117·60	0·2105	523·7	463·4
10·00	147·00	132·30	0·1953	554·0	494·0
15·00	220·50	205·80	0·1465	681·0	621·0
20·00	294·00	279·30	0·1195	781·0	721·0
25·00	367·50	352·80	0·1020	864·0	804·0
(1)	(2)	(3)	(4)	(5)	(6)

The diagram (Fig. 4), which was used to illustrate Mr. Saunders' lecture, shows graphically the heat d pressing air with initial temperatures at the inlet-v and 100°

cylinders were not applicable to the air-cylinders; so that an ordinary oil-cup was in use. About $\frac{1}{8}$ pint of oil was put into the oil-cup on each cylinder four times during the working day of 10 hours, or say $\frac{1}{2}$ pint per day. When the oil was put into the cup and the tap slightly opened, it was probable that all the oil would be sucked into the cylinder during the course of the next two or three strokes. This method of feeding the cylinders with oil was no doubt objectionable, and judging from the amount of the deposit of oil or mixed oil and coal-dust found in the air-receiver, it would appear that a larger quantity of oil was put into the air-cylinders than could be used in lubrication, and that the surplus was carried along with the air into the air-receiver. It was also thought that the flashing and ignition-points of the oil might not be so high as had been stated by the vendors; and, further, that the deposit, either some residue of the oil, or a mixture of the oil and fine coal-dust, found on the discharge-valves, air-passages, and in the air-receiver, had in some way contributed to the cause of the explosion. As the makers of the oil suggested that an independent test should be made of the oil and the deposit, a sample of oil taken from the oil-can in use at the time of the explosion (marked No. 1), and a sample taken from the cask in the stores as it was received from the makers (marked No. 2), and a sample of the deposit, were submitted by the manager to Mr. Boverton Redwood for his examination. Mr. Boverton Redwood reported as follows:—

The two samples of oil gave the following results:—

Samples.	Flashing-point. Close Test.	Flashing-point. Open Test.	Ignition-point.
No. 1 ...	454° Fahr. ...	529° Fahr. ...	594° Fahr.
No. 2 ...	460° Fahr. ...	524° Fahr. ...	588° Fahr.

On making an analysis of sample No. 1, I found that it yielded 21 per cent. of saponifiable matter, and it therefore may be considered to consist to this extent of some fixed oil, the balance being mineral oil. The term fire-test is that which is usually employed in the trade to indicate the point at which an oil when gradually heated in an open cup, in an instrument constructed for the purpose, ignites on the application of a flame and continues burning.

The black deposit from the receiver gave the following results:—

Volatile matter	55·8 per cent.
Fixed carbon	37·3 ,,
Ash	6·9 ,,

As the proportion soluble in ether only amounted to 2 per cent., it is probable that the deposit largely consists of something in the nature of coal-dust, though microscopic examination indicates that, if coal be present, it is in a very finely divided state. You are probably familiar with the old lecture-experiment of producing the ignition of a piece of tinder inserted in the closed end of a small air-compressing syringe, and you will therefore readily understand that the presence of any inflammable dust in the atmosphere of an air-compressor may produce an explosion. I have also had experience in my professional work of the effect of the pre-

sence, in an atmosphere containing inflammable dust, of even a very small proportion of inflammable vapour in increasing the risk of explosion. It is possible that the presence in the lubricant of a fixed oil may likewise augment the liability to ignition when the air in the cylinder is compressed, as fixed oils are all more or less oxidizable, while mineral oils are practically not subject to that action under such circumstances.

As the results of Mr. Boverton Redwood's tests did not vary much from the oil-makers' figures, as to the flashing and ignition-points, no fault could be found with the oil in those respects. Most of the leading makers of high-grade cylinder-oils were then communicated with, and asked whether they could supply an oil having higher flashing and ignition-points than those stated, but they did not appear able to do so. With such high temperatures of the compressed air, as given in Table I., it was now considered not to be safe to use oil in the cylinders, and the makers of the air-compressor recommended that a solution of soft soap in water, in the proportion of 1 pound of soft soap to 6 gallons of water, should be used in lieu of oil. This suggestion was adopted, and the mixture of soft soap and water was used for several weeks, but it was found not to sufficiently lubricate the pistons; the cylinders commenced grooving, and they would soon require to be re-bored; and the clearance-space between the piston and the cylinder-cover was filled up with sediment in about a week or ten days. So as to have as small a quantity of sediment as possible in the cylinder, various qualities of soft soap were tried, the best and purest being that made from olive oil. The quantity of the mixture of soft soap and water was increased from day to day, until 9 gallons per day were used in each cylinder; but still the pistons and cylinders were not sufficiently lubricated, and the clearance-space in the cylinders was filled with sediment in about three days, so that the cylinder-covers had to be taken off every three or four days to clean out the sediment. Another difficulty experienced, in lubricating the cylinders with soft soap and water, was that the water was carried to, and exhausted from, the hauling-engines, which would in frosty weather have caused the exhaust-ports of the hauling-engines to freeze up. It is probable that the mixture of soft soap and water put into the cylinders would have the effect of cooling the air, but from what has been previously stated, the conclusion was come to that the use of soft soap and water for lubricating the pistons and air-cylinders was not satisfactory, and would have to be abandoned.

Since the air-compressor was erected at Clifton colliery, more than 20 years ago, great improvements have been made in the construction of

air-compressors in this and other countries, both in efficiency and safety. The makers of the Clifton air-compressing machines now make the inlet-valves and discharge-valves of larger area, and place them in the cylinder-covers. They are also made on the compound principle, the air being compressed in the first cylinder to a pressure of from 30 to 35 lbs.; it then passes through a cooling apparatus to the second cylinder, where it is compressed to a pressure of 60 to 70 lbs. per square inch. In some air-compressors the inlet and discharge-valves are controlled by a positive valve-motion, instead of opening and closing automatically. By these improvements, the air enters the cylinder through the inlet-valves and is discharged through the outlet-valves more freely than in the old form of valves, and is also kept much cooler than it is by single stage compression. The Clifton colliery air-compressors were dealt with in their original construction, by seeking some remedy for cooling the compressed air below the temperatures shown in Table I.

The importance of keeping the compressor-house as cool as possible, in order to have a low initial temperature, had not been ignored, but owing to the fact that coal-sorting was carried on quite close to the engine-house windows, those nearest to the air-cylinders were generally kept closed to exclude the dust as much as possible; but even then, it is probable that coal-dust in a finely divided state was imperceptibly drawn into the air-cylinders. These conditions were not present at the time when the compressor was erected, and it is only a few years since the necessity arose for the coal-sorting to be done near the compressor-house.

When the compressors at Clifton colliery were erected, and until the explosion took place, the water-tanks, which enclosed the air-cylinders, allowed the water to enter near the bottom and rise to the height indicated at the point HH^1 (Fig. 3, Plate XXXI.), where it overflowed. The quantity of cold water supplied to each cylinder was about 6 gallons per minute, and the temperature (about 60° Fahr.) increased very slightly as it approached the overflow, until within about 6 inches of the top, and where the discharge-valves and air-passages are situated, the temperature of the water at the overflow averaged 116° Fahr. The air-passages and the discharge-valve chest, the hottest parts in connexion with the air-cylinder, which should have been covered with the greatest depth of water, were left bare. The water-tanks were, therefore, raised to allow of the water rising and overflowing at the point JJ^1 (Fig. 3, Plate XXXI.). It will be seen that the discharge-valve chest covers K, and the air-passages E are now covered with water to a depth of 10 inches. The quantity of water supplied at G^1 and G^2 was increased to 18 gallons per minute to each

tank, and had the effect of reducing the temperature of the compressed air from 420° to 350° Fahr., and the temperature of the water in the tanks from 116° to 86° Fahr., when the engine was running full speed. It was now considered safe to again use oil for lubricating the pistons and cylinders The old oil-cups were removed and a $\frac{3}{8}$ inch snifting-valve was fixed on each air-cylinder. The oil is supplied to these snifting-valves in drops, which are sucked into the cylinder drop by drop by the action of the piston. It has been found that 80 drops of oil per hour are sufficient to keep each cylinder well lubricated, and scarcely any oily deposit is now found on the discharge-valves, or in the air-passages and air-receiver, as compared with the large quantity found on previous occasions when more oil was used.

With the view of ascertaining the cause of the explosion, Mr. Henry Fisher, the manager, communicated with Mr. Boverton Redwood to ask his opinion thereon, and with Mr. W. L. Saunders. Mr. Boverton Redwood reported as follows :—

In the use of such an oil as that which I have just examined for you in the internal lubrication of air-compressing cylinders, in which the temperature of the air has been shown by the pyrometer to be as high as 600° Fahr., there would be considerable volatilization of the more volatile hydrocarbons present, and the mixture of vapour and air thus formed might doubtless be explosive; but the difficulty is to account for its ignition in the absence of an electric spark or a flame, or contact with a metallic surface heated to a sufficiently high temperature. I have, however, already suggested that such a deposit as that which I analysed for you some time ago might become ignited, and that in its turn might determine the explosion of such a mixture of oil-vapour and air as I have described.

Mr. Wm. Saunders replied as follows :—

Ignition in compressed-air discharge-pipes and passages is not uncommon in America. At times this ignition is in the nature of an explosion. Two air-receivers were blown up during the construction of the New York aqueduct, and in one case the engine-room was destroyed by fire resulting from the explosion. We have also records of two other cases where spontaneous explosions in air-receivers have resulted in the destruction of the engine-room by fire. Other instances occur where ignition takes place near the air-compressor, the pipes becoming red hot at the joints. This ignition has been known to extend into the air-receiver, and in one instance the flames were carried down into the mine by the compressed air.

It is plain that the cause of the explosion or ignition is an increase of temperature above the flashing-point of the oil which is used to lubricate the compressors. A thick or cheap grade of cylinder-oil should never be used in an air-compressor. Thin oil which has a high flashing-point and which is as free from carbon as conditions of lubrication will admit, is the best oil. If the temperature of the air before admission to the compressor is 60° Fahr., and it is compressed to 58·8 lbs. gauge-pressure, the final temperature, where no cooling is used during compression, will be 369·4° Fahr., or a total increase of 309·4° Fahr. If air admitted at 60°

Fahr. is compressed without cooling to 73·5 lbs. gauge-pressure, the final temperature will be 414·5° Fahr., and the total increase of temperature 354·5° Fahr. Under such circumstances the question naturally arises, how is it possible when using oil with an ignition-point of 600° Fahr. to obtain ignition, especially as water-jackets and ot her methods of cooling are used which should have reduced the final temperature? The figures are also based on dry air which increases in temperature during compression to a greater degree than moist air, and it is known that air that is used in compressors is never very dry. The theoretical figures show that in order to get ignition with the oil mentioned, the gauge-pressure should be about 200 lbs. per square inch, where no cooling takes place. It is plain that there must be an increase of temperature, or ignition would not take place. This increase of temperature may result either from increase of pressure which is not recorded on the gauge, or there may be an increase of temperature without a corresponding increase of pressure. A badly designed compressor with inefficient discharge-passages might cause trouble by increasing the pressure, momentarily carrying with it a higher temperature. But we have known instances where ignition has occurred in a well designed system, hence we must look for other causes. In our judgment, the majority of cases may be traced to an increase of temperature without a corresponding increase of pressure; this increase of temperature can only be excessive where the temperature of the incoming air is excessive. A hot engine-house from which air is drawn into the cylinder is a bad condition. We have known cases where the incoming air was drawn from the neighbourhood of the boilers, the temperature being close to 150° Fahr. This means, of course, that if the total increase of temperature when air is compressed to 73·5 lbs. gauge-pressure is 354·5° Fahr., the temperature of the initial air should be added to this figure, and thus the final temperature might be 504·5° Fahr.

But we have known ignition to take place when the temperature of the incoming air was normal, when the discharge-passages and pipes were free and of ample area, hence we must look for some other cause. The only possible explanation is that the temperature of the incoming air is made excessive by the sticking of one or more of the discharge-valves, or fitting badly in their seating, thus letting some of the hot compressed air back into the cylinder to influence the temperature before compression, and it is not difficult to understand a leaky discharge-valve letting enough air back into the cylinder to increase the initial temperature to 200° or 300° Fahr. If so, and we are compressing air to 73·5 lbs. gauge-pressure, we have, say 300° temperature in the free air before compression, and as the increase is 354·5° the resulting temperature might be 654·5° Fahr.

As a remedy, we would suggest more care in selecting the best air-compressor, and in frequent cleaning of the discharge-valves and passages. The best air-compressors are built so that the discharge-valves may be readily removed; these valves should be cleaned regularly once a week by the engineer, who should make sure that they fit properly. It is impossible to get good lubricating-oil that is free from carbon, hence there will always be more or less carbon deposited on the discharge-valves, but this must not be allowed to accumulate.

Inter-coolers between the air-cylinders, and after-coolers between final cylinder and receiver are also recommended. The best inter-coolers are made of nests of brass tubes, the air passing around the tubes and water through them, hence there is a thorough splitting up of the air and efficient cooling. One of these coolers located in the discharge-pipe will absolutely prevent the passage of flame and will ensure the protection of the mine against fire, even though there be ignition at or near the air-cylinder.*

* *Compressed Air* [New York], July, 1897, page 257.

The published accounts of explosions that have occurred, owing to the high temperatures developed during compression of air, give some idea of the dangers attending such temperatures, and it is very desirable that they should be mitigated as far as possible.

Table III. will enable a comparison to be made of the different conditions under which explosions and ignitions have taken place in air-compressing plants, and although other explosions have occurred in this country, and on the continents of Europe and America, the details have not been published, so far as the writer is aware.

TABLE III.

Name of Colliery.	Speed of Engine.	Oils for Lubricating Air-cylinders.		Working Pressure in Air-receiver.	Temperature of Compressed Air.	Remarks as to Presence or otherwise of Coal-dust.
		Flashing-Point.	Ignition-Point.			
	Revols.	Degs. Fahr.	Degs. Fahr.	Lbs. per Sq. Inch.	Degs. Fahr.	
*Ryhope ..	23 to 24	365	—	50	—	Coal-dust present.
†Newbattle ...	—	295	—	50	320 to 370	No dust.
‡Kaiserstuhl I.	32	523	675	70	—	Coal-dust present, cotton-wool filters used.
‖Clifton .	48	529	594	60	400 to 420	Coal-dust present.
	(1)	(2)	(3)	(4)	(5)	(6)

* Air-receiver and pipes in shaft, etc., destroyed. † No explosion and no damage. ‡ Air-receiver destroyed, and much damage done. ‖ Explosion in air-receiver, but no damage done.

The difference in the results of the four accidents will be seen in the column of remarks. Serious damage occurred through the bursting of the air-receivers, and pipes at both Ryhope and Kaiserstuhl I. collieries; but at Newbattle and Clifton collieries, no damage was done to the plant, the accident at Newbattle being a simple ignition in the pipes leading from the air-compressor to the air-receiver; whilst at Clifton the ignition spread to the air-receiver, where a quantity of inflammable vapour was exploded. In column 6, it will be noted that no coal-dust was present in the air at Newbattle; and at Kaiserstuhl I., cotton-wool filters were used to keep out the dust, so that if the filtration was effective, then it may be assumed that both these accidents arose from the decomposition of the surplus oil, which was carried from the air-cylinders, and deposited in the pipes and air-receivers. With regard to these oils, the flashing-points given vary considerably, and whilst nothing is known as to the ignition-point of the oils used at Ryhope and Newbattle, those at Kaiserstuhl I. and Clifton are tabulated, and it would be difficult to imagine that any danger existed in using oils giving such good results. Referring to column 5, it would appear that the temperature of the compressed air had been

registered at Newbattle only, at the time of the accident, and that no attached thermometer was in use at the other collieries, the temperature of the compressed air at the Clifton colliery being taken after the accident, but under precisely the same conditions of working.

Both the manager and the writer have formed an opinion as to the cause of the explosion of the air-compressors at Clifton colliery. It has been made evident that the temperature of the compressed air had been and can be raised to such a degree as to volatilize the oil into a vapour in the condition for ignition; but, as Mr. Boverton Redwood and Prof. Bedson have pointed out, it is difficult to explain how the oil-vapour can be ignited by a still further rise in temperature, unless a spark or flame be produced in contact with the vapour. We think that it is possible for a spark to be produced in the cylinder by the friction of the piston if allowed to work in a dry state, and also in the discharge-valve chest for the same reason, with the form of valve used in these air-compressors. Prof. Bedson, writing of the Ryhope and Newbattle explosions, refers to the possibility of the oil and the deposit oxidizing, and thus producing sufficient heat to ignite the explosive mixture. From the incandescent state in which the deposit had evidently been, and assuming that it contained some coal-dust, which is almost certain, making it more readily oxidizable, the probability is that, by the large quantity of air at a high temperature continually passing over it, it became oxidized and spontaneously took fire, and so ignited the inflammable mixture of oil-vapour and air.

The lessons to be learned from the explosions described in this paper and in the appendix are:—

1.—The atmosphere in the engine-house must be kept as cool as practicable, so as to admit the air to the compressing-cylinder at as low an initial temperature as possible. Passing the inlet-air through a freezing mixture has been suggested for the purpose.

2.—The inlet-valves and discharge-valves must be made of as large an area as practicable, and so as to freely open and close. The valves are preferably made to open and close by positive valve-gear, actuated by the engine, instead of automatically opening and closing.

3.—The temperature of the air must be kept as low as possible during compression, by surrounding the cylinders and covering all air-passages and discharge-valve chests with water in jackets, and providing for the constant circulation of an ample supply of cold water through

the jackets; and also by compounding or compressing the air in two stages, and, in addition to cooling as above, forcing the air through a cooling apparatus between the low-pressure and high-pressure cylinders. Water-spray injections, together with compounding, have been introduced by Prof. Riedler in Paris, and are said to yield good results.

4.—A thermometer must be kept affixed to the air discharge-pipes as near as practicable to the discharge-valve chest, and in sight of the engineman, to register the temperature of the compressed air; and if the temperature exceeds, say, 350° Fahr., the engine must be stopped until the air has cooled down.

5.—An oil shall only be used in the cylinders having the highest flashing and ignition-points obtainable, and only in such quantity as is necessary for the efficient lubrication of the pistons and cylinders, so as to avoid the accumulation of any surplus oil on the discharge-valves, air-passages, and receiver.

6.—As far as possible, coal-dust must be prevented from being drawn into the air-cylinder along with the air through the inlet-valves. Passing the air through cotton-wool filters in front of the inlet-valves has been suggested for this purpose.

7.—The discharge-valves, air-passages, and air-receivers must be always kept clean and free from all oily or other deposit.

The object that the writer had in view in bringing this subject before the members of this Institution was to draw attention to some very serious conditions which may be present in many air-compressing plants at work even to-day, conditions which, if not discovered and removed, may cause accidents and even loss of life.

In conclusion, the writer would wish to thank Mr. Henry Fisher, agent and manager of the Clifton colliery, for the valuable assistance and information, given so readily, in the preparation of this paper.

APPENDIX.—SUPPLEMENTARY NOTES ON EXPLOSIONS IN AIR-COMPRESSORS AND AIR-RECEIVERS.

*Ryhope Colliery.**

On March 1st, 1883, an explosion occurred in the air-receiver on the surface and in the pipes in the shaft at Ryhope Colliery, causing considerable damage. The main points of interest in connexion with this explosion, which are taken from the above report, are as follow:—The air-compressors had two air-cylinders, 33 inches in diameter and 5 feet stroke, fitted with water jackets, the ends as well as

* "Report of the Committee appointed to inquire into the Explosion of an Air-receiver at Ryhope colliery," drawn up by Mr. M. Walton Brown, with an appendix by Prof. P. P. Bedson, *Trans. N.E. Inst.*, vol. xxxvii., page 197.

the sides being supplied with water for cooling purposes. The usual speed of the engines varied from 23 to 24 revolutions per minute. The lubricant used at the time of the explosion was a mixture consisting of:—Soft soap 2 lbs., mineral oil ½ gallon, and water ½ gallon, and 1 gallon of the mixture was poured into the suction-valves of the two cylinders every 2 hours.

The No. 1 air-receiver on the surface, which exploded, was an egg-ended boiler, 6 feet in diameter by 29 feet long, arranged to blow off at a pressure of 50 lbs. per square inch, from which the air was taken down the shaft (about 1,500 feet) by malleable iron pipes 9 inches in diameter to No. 2 air-receiver (4 feet in diameter by 12 feet long), and thence to three hauling-engines.

The explosion occurred at 10·40 p.m., and was accompanied by bright flames from 20 to 30 feet high, which immediately subsided, leaving a fierce fire burning brightly within the receiver. The engineman was struck on the head with some flying *débris*, and rendered unconscious for a time. No thermometer was in use at the time, but it was stated that the temperature of the compressed air was usually about 180° Fahr., but had been registered at 300° Fahr. The pipes leading from the air-cylinder to No. 1 air-receiver had not been cleaned for 12 months previous to the accident, and when afterwards examined a deposit 1½ inches thick was found in the bottom of the pipes; this deposit extended into No. 1 air-receiver, where it was found all over the bottom to the depth of about 2 inches. The deposit was evidently a mixture of coal-dust and the lubricant carried over from the air-cylinders.

The receiver was blown into four pieces, one end was nearly blown off, being ripped open and laid out flat. The plates had evidently been subjected to intense heat. Some other damage was done on the surface, and the pipes and the brattice-wall in the shaft suffered most seriously. At the depth of 762 feet, one segment of the cast-iron tubbing was found blown about ½ inch outwards from the pit; at 1,080 feet, several pipes were partially split open; from 1,200 to 1,272 feet, the pipes, brick-brattice, side-buntons, etc., had all fallen down the pit. The pipes and brattice lower down the shaft were also much damaged. No. 2 air-receiver, at a depth of about 1,500 feet, was displaced, and had fallen to the bottom of the pit. The effect of the explosion was felt at considerable distances from the shaft, an air-crossing being lifted at a point about 3,000 feet inbye.

As to the cause of the explosion, it was thought possible that the flashing-point of the mineral oil forming part of the lubricant used in the air-cylinders might have been lower than the temperature of the compressed air: in which case the receiver might have been filled with an explosive mixture of air and oil-vapour. The oil, being tested, showed that at 230° Fahr. about 1 per cent. was volatilized daily, and at 500° Fahr. about 9 per cent.: the flashing-point being 365° Fahr. It seemed difficult to understand how an explosive mixture could be formed in the air-receiver owing to the considerable excess of air which would be present, or how it could be ignited.

Prof. P. P. Bedson, at the request of the committee, made experiments "to ascertain the temperatures at which coal-dust alone and the deposit found in No. 1 air-receiver were ignited, when heated in a current of air at ordinary and higher pressures. It was found impossible to produce combustion of the deposit, although the temperature of the air at atmospheric pressure was raised to 450° Fahr.; but, with coal-dust alone, ignition took place at a temperature of 291° Fahr., and the mass finally glowed with a dull red heat. Further experiments were made with air at a pressure of 60 lbs. per square inch, the results of which showed that the temperature of ignition of coal-dust was the same as with air at ordinary pressures, but when ignition occurred, a more intense heat was produced, as shown by the

coking of the dust. It appears to be highly probable that under a pressure of 60 lbs. per square inch, the deposit, consisting of a mixture of coal-dust, mineral oil, soft soap, and moisture, might have been ignited in the same manner as in the experiments with the coal-dust, although no such phenomenon was produced in the experiments. This supposition receives some support from the evidence of heating in the various parts of No. 1 air-receiver. It seems possible, therefore, assuming that the deposit was in a state of ignition, for destructive distillation of a portion of the deposit to take place, forming considerable volumes of combustible gases, which would be exploded as soon as the mixture, consisting of the proper proportions of air and the gas (from the distillation of the oil and coal-dust contained in the receiver), was ignited by the burning deposit."*

Prof. Bedson, in concluding his remarks upon his experiments, said that: "(1) It is shown that with an easily oxidizable material, such as coal-dust, it is only necessary to accelerate the oxidation by heating the dust, in contact with air, to a temperature within the limits of those likely to be reached in compressing air to 58 lbs., in order to bring about, in the course of time, the ignition of the dust. (2) These results have been possible, even when experimenting with a comparatively small amount of material, an influence of importance, as is shown by the results obtained in the two different series of experiments made, the conditions of which differed essentially only in the amount of coal operated upon. In the second series, with 1 oz., a temperature of 356° Fahr. was required for ignition; whilst in the third series, with 10 ozs., the temperature required was reduced to 291° Fahr. Despite the fact that the one or two experiments made with the deposit found in the Ryhope air-receiver, made under conditions similar to those in which coal-dust was successfully ignited, were not in a like manner successful; still, as there can be no doubt that this material is of a nature somewhat akin to the coal-dust entering so largely into its composition, and, like it, capable of being oxidized by the oxygen of the air, the constant exposure of this substance to the action of air heated by compression must result in the acceleration of the oxidation, and, as with the coal-dust, in a rise in temperature, until in some portion of the mass local ignition commences. Combustion once begun at any point in the mass, the conditions are most favourable to its rapid extension. Further, the heat generated by a combustion of a portion of the mass might serve to distil destructively neighbouring portions, and thus give rise to the formation of combustible gases, which, mixing with air, would form an explosive mixture. An explosive mixture formed under these conditions would be readily ignited by contact with the already burning material."†

The writer is informed that, since the accident occurred at Ryhope colliery, the air-compressor has been altered so as to compress the air in two stages with intermediate cooling, which greatly reduces the temperature in the air-cylinders and passages.

Newbattle Colliery, Dalkeith.‡

On February 13th, 1888, an ignition took place at Newbattle colliery in the pipes leading from the air-compressors to the air-receiver, about 50 feet distant, without, however, causing any damage beyond blowing out some of the joints of

* *Trans. N.E. Inst.*, vol. xxxvii., page 203. † *Ibid.*, page 212.

‡ "The Danger Attending the Use of Light Mineral-oils for Lubricating Air-compressing Machinery," by Mr. John Morison, *Trans. N.E. Inst.*, vol. xxxviii., page 3.

the pipes. The air-receiver worked up to a pressure of 50 lbs. per square inch, and was blown off daily. The single air-cylinder, 24 inches diameter by 4 feet stroke, was fitted within a water-tank in the usual way, which caused the cylinder to be surrounded by water. The temperature of the compressed air at 50 lbs. pressure varied from 320° to 370° Fahr. A short time previous to the ignition, the engineman had noticed that the pipes leading to the air-receiver were unusually hot, but did not attach much importance to the fact; soon, however, the pipe-joints began to blow, sparks were seen issuing with the air, and the pipes became nearly red-hot. When the joints were broken to examine the pipes, their interior was found to be coated with a charred deposit, the residue of the combustion of lubricating-oil which had been used in the air-cylinder and gradually deposited in the pipes. This had evidently been incandescent.

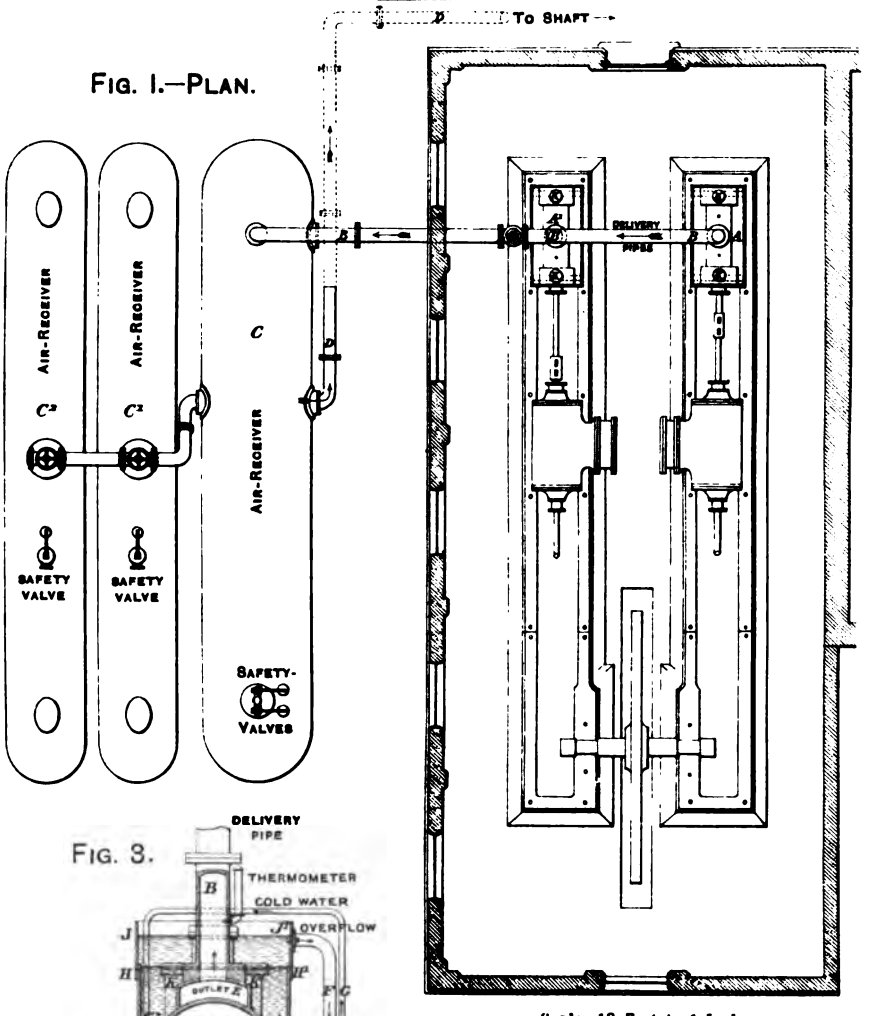
Upon enquiry it was found that instead of lard-oil being used for lubricating the air-cylinders, according to the instructions given, the engineman had substituted a mixture of heavy mineral oil and an oil bought as "colza." The flashing-point of the former was 480° Fahr., and of the latter 295° Fahr. There was no coal-dust present, and Mr. Morison stated in his paper that—"The absence or presence of coal-dust has, I think, little to do with the result . . . . for it seems evident that if the temperature of the compressed air at any point, say, beyond the discharge-valves, is 360° Fahr., which is possible and common in any compressor working without special means of cooling beyond the water-jacketed cylinder, the temperature at some point in the interior of the cylinder at the moment of maximum compression, and, therefore, when the discharge-valves are open, must far exceed this, and would be sufficiently high to vapourize oil such as was used in both cases and by flashing to ignite the vapour." *

During the discussion upon Mr. Morison's paper, Prof. P. P. Bedson wrote that—"As will be seen from the Appendix to the Report of the Ryhope Committee, I concluded that, in the case under consideration, the chief heat-producer was to be found in the carbonaceous deposit found lining the pipes and receiver, the production of heat being effected by the oxidation of this material by air passing over it and having its temperature raised by compression. To simplify the matter I experimented with certain of the components of this mixture, and first studied the effect of heating coal-dust alone in a current of air, with the result that it was found possible to ignite the coal-dust by heating it to a temperature varying from 291° to 320° Fahr. Further, when coal-dust is mixed with 30 per cent. of its weight of the oil used at Ryhope as a lubricant, the ignition of the dust takes place at a slightly higher temperature, and the inflammation takes place more slowly, in fact the coal-dust, etc., do not ignite until the greater proportion of the oil has been vapourized. . . . . The conclusion that the 'oil' has been the cause in both cases cannot be summarily dismissed. . . . . Where is the heat to come from, which will raise the vapour, or a portion of the oil to its ignition-point? The 'flashing-point' must not be confused with the 'ignition-point' the former being simply the temperature at which inflammable liquid gives off vapours in sufficient quantity to be ignited by a light, the latter being the temperature to which the vapours must be raised in order that they may burn. Whilst the oil used at Newbattle is known to have a flashing-point of 295° Fahr., there is nothing stated with regard to its 'ignition-point,' or the temperature of ignition of its vapour. I am not aware that any direct experiments

* "The Danger Attending the Use of Light Mineral-oils for Lubricating Air-compressing Machinery," by Mr. John Morison, *Trans. N.E. Inst.*, vol. xxxviii., page 6.

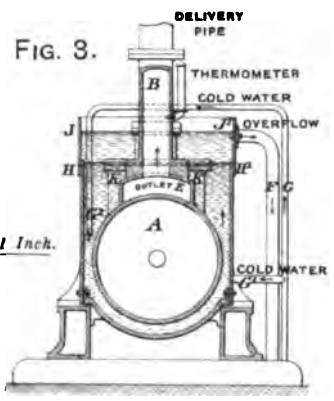
To illustrate Mr. T. G. Lee's Paper on "Explosions in Air-Compressors and Receivers."

FIG. 1.—PLAN.



Scale, 12 Feet to 1 Inch.

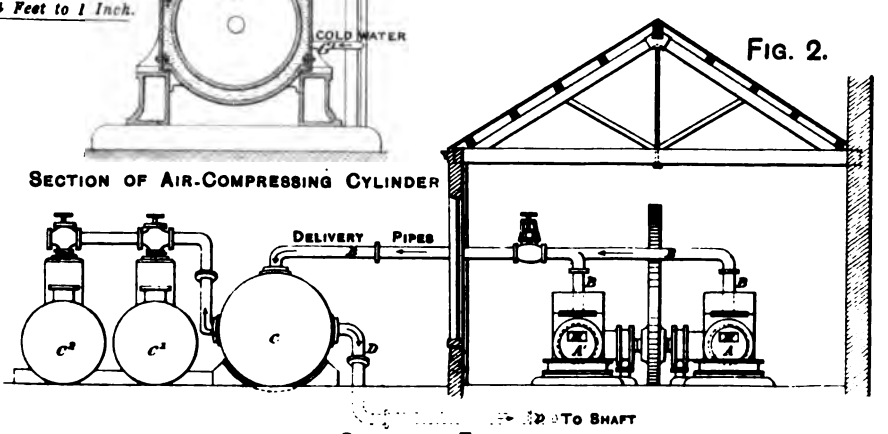
FIG. 3.



Scale, 4 Feet to 1 Inch.

SECTION OF AIR-COMPRESSING CYLINDER

FIG. 2.



SECTIONAL ELEVATION.

have been made to determine the temperature of ignition of the vapours given off from such oils, but I should imagine that a temperature of at least dull redness would be required to start ignition. How, then, is such a temperature to be reached? My experiments suggest that such temperatures can be obtained when working air-compressing machinery, such as that used at Ryhope or Newbattle, by the accumulation of the heat produced by the slow oxidation of the lubricant or oxidizable materials forced into the receiver and pipes. Consequently, if the oil is to be considered the sole cause of the phenomena, it must be demonstrated not only that it is in part volatilized at the temperatures of working, but that it undergoes oxidation under these same conditions, and that the heat produced would suffice to ignite the vapour of the oil, and produce the charred deposit, such as Mr. Morison describes as existing in the pipes between the compressor and the receiver. If this be demonstrated, and I do not see that it is impossible, then greater weight must be given to the part played by the oil than perhaps I have done in the Appendix to the Report already referred to. But, if it is a question between coal-dust and a mineral oil as heat-producers, when undergoing slow oxidation, I should imagine that the preference must be be given to the more easily oxidizable coal, rather than to the stable hydrocarbons constituting the oils used."†

Kaiserstuhl I. Pit, Dortmund, Westphalia.

An explosion took place on April 30th, 1896, in the air-compressing plant at the Kaiserstuhl I. pit of the Westphalia colliery at Dortmund, which was attended with serious consequences. Details of this explosion are published in volume xiv.† of the *Transactions* of The Federated Institution of Mining Engineers.

The CHAIRMAN (Mr. G. B. Walker) said that at Wharncliffe Silkstone colliery, an occurrence similar to that mentioned by Mr. Lees had taken place, though not on a violent scale. There was a chance of very serious results accruing from the emission into a mine of the burnt gases from the receiver when the oil and coal-dust became ignited. He thought that Mr. Lees was right in assuming that a large amount of coal-dust passed into the cylinder with the air. The floor of an engine-house, and the engine itself, if not continually dusted, were covered with fine coal-dust; and a large quantity of coal-dust was drawn through the cylinders, and thence into the air-receivers. Then, oil was carried with the compressed air into the air-receiver, and a deposit took place in the receivers and adjoining pipes in almost every case. He was afraid that it was impossible to keep coal-dust out of the cylinder by means of filtering through cotton wool or any such device, as the in-draught was too strong. If once a month, or at some such interval, the receivers

* "The Danger Attending the Use of Light Mineral-oils for Lubricating Air-compressing Machinery," by Mr. John Morison, *Trans. N.E. Inst.*, vol. xxxviii., page 8. † Page 615.

were cleaned as a boiler was cleaned, and the pipes (so far as they could be) were scraped by means of scrapers at the end of rods, he thought that they would have done all that was practicable in that direction.

Mr. G. J. BINNS (Netherseal colliery) asked whether there was any record dealing with the changes undergone by mineral oils when maintained continually at high temperatures. He suggested that if Mr. Boverton Redwood made a test of that sort, it would throw some light on the cause of these disastrous explosions. He used soft soap entirely for lubricating air-compressing machinery; it had had no bad effects so far, and it was excessively cheap, as they used so very small an amount. It would be desirable to try Mr. Lees' suggestion, as to filtering the air, and see how it acted. If it did not take out all the dust, it might take out a great proportion of it.

Mr. T. G. LEES said that he was not aware that any records existed of trials of the changes that took place in mineral-oil subjected to high temperatures for a lengthened period, and he thought that it would be a difficult matter to ascertain by experiment, unless the same conditions were maintained throughout the trials, that existed in the inside of an air-compressing cylinder. Simply keeping the oil at the necessary temperature and pressure for a certain length of time would probably not give the results that would be obtained in an air-cylinder, as in the latter a fresh supply of oxygen is drawn in with the air at every stroke, thus intensifying the action of oxidation. Cotton-wool filters (which are not the writer's suggestion) had been adopted on the continent for freeing the air from dust, and were in use at the Kaiserstuhl I. colliery, Westphalia, at the time of the recent explosion.

The CHAIRMAN moved a vote of thanks to Mr. Lees, and further discussion was adjourned.

The following paper by Mr. R. Cremer on "The Walcher Pneumatophore, and the Employment of Oxygen for Life-saving Purposes," was read:—

THE WALCHER PNEUMATOPHORE, AND THE EMPLOYMENT OF OXYGEN FOR LIFE-SAVING PURPOSES.

By RICHARD CREMER.

Amongst the numerous dangers to be overcome by the mining engineer, that arising from the occurrence of poisonous gases, or a deficiency in the proportion of oxygen in the atmosphere, is one of the most difficult to be encountered. This danger may be caused by an explosion of fire-damp, and the resulting accumulation of after-damp, by stagnant accumulation of carbonic acid, or by underground fires. It was well known how much, especially in recent years, the safety of workmen, engaged in mines, had been increased; and it was cheering to note that the endeavours to reduce the number of fatalities from accidents, by means of apparatus and arrangements for rescue, showed similar results.

The first necessity for the rescue of endangered lives was to bring the men out of the stupefying influence of the gases into a respirable atmosphere, or the replacement of such gases by fresh air. In order to bring men as quickly as possible out of the deadly influences of after-damp, much ingenuity had been directed to the devising of apparatus, which would render it possible for the rescuers to enter and remain a sufficient length of time in a dangerous atmosphere. Of such appliances, there were at present a considerable number, from the simple device of a sponge soaked in vinegar to the most ingenious: the majority having, in the first instance, been devised for use at fires, and later adapted for underground use.

In connexion with coal-mines, the want of such apparatus, in the case of explosions and underground fires, had been more especially appreciated during the last decade. When one considered that in the case of an explosion of fire-damp or coal-dust, by far the greater number of fatalities were attributed to the carbonic acid and carbonic oxide contained in the after-damp, it appeared an obvious duty to endeavour to provide ways and means for reducing, as much as possible, the loss of life due to this cause. Dr. Haldane, in his report to the Home Secretary *On the Causes of Death in Colliery Explosions and Underground Fires*, proved that 80 per cent. of the fatal cases were not attributable to the direct action of explosion, but to the after-damp thereby produced, and that a

large proportion of these lives could be saved if the victims could be quickly brought out, or if the after-damp could be equally quickly removed by ventilation.

Of the appliances, which have from time to time been devised for the purpose of enabling a rescue-party to penetrate into irrespirable atmospheres, two classes are to be specially distinguished. The first of these comprises means for supplying, through a flexible pipe, fresh air for breathing to the rescuer. Amongst such appliances which have been introduced, and more particularly for use in case of fires, may be mentioned the apparatus of Messrs. Denayrouze, Müller von Bremen, Loeb, and Stotz. Although these appliances may have been used more or less successfully in colliery disasters, and under favourable conditions may be capable of rendering very efficient service, they have all of them the great disadvantage for colliery use, that the distance to which the rescuer can penetrate into the poisonous or irrespirable atmosphere is limited to at most 300 feet, and his own life depends on the attention and exertion of the person or persons supplying or forcing the air to him. Moreover, such apparatuses have the great defect that they are not sufficiently soon procurable and available. Quite otherwise, and of much greater importance for mines, is the second class of apparatus which permits a rescue-party, immediately after a colliery-disaster, to penetrate to any required distance into the workings filled with after-damp, and to bring the survivors out of the influence of the dangerous atmosphere, and which is quite independent of auxiliary appliances or local conditions. To this class of life-saving apparatus belong respirators, reservoirs, and oxygen apparatus, or, as fittingly defined by Dr. Fillunger,* those in which the freedom of movement of the user is unrestricted, whilst the time of use is restricted, in contradistinction to the first-mentioned class, in which the time is unrestricted, whilst the freedom of use is restricted.

Of the apparatus allowing unrestricted movement only the oxygen-appliances with devices for revivifying the respired breath are of importance for use in mines. The merit of producing the first of such apparatus belongs to Prof. Schwan of Belgium ; followed later by the invention of Mr. Henry Fleuss, of London, and more recently by Messrs. Von Walcher-Uysdal and Gärtner, assisted by Mr. Rössner, who have designated the apparatus, constructed by them, the "pneumatophore."

The principle at the root of all the three inventions is the same—

* "Respiratory Life-saving Apparatus for Mines," etc. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv., 1896, pages 581-585 and 591-598 ; and *Trans. Fed. Inst.*, vol. xii., page 693.

viz., revivification of the respired air, and the replacement of the consumed oxygen. With respect to the physiological action or influences which occur when such apparatus are used, Dr. Fillunger stated that:—

During respiration, a portion of the oxygen of the atmosphere is consumed by combination with the carbon in the blood, forming carbonic acid, which is expired with the remaining oxygen and the nitrogen, which plays no active part during the respiration. A healthy person respires from 5 to 8 litres (300 to 500 cubic inches) of air per minute, during which the consumption of oxygen varies from 300 cubic millimetres (0·018 cubic inch) when the muscles are at rest, and 1,100 cubic millimetres (0·067 cubic inch) when the muscles are in action. The amount of carbonic acid expired varies naturally within small limits, and the carbonic acid thrown off increases with the consumption of oxygen, and for every kilogrammetre of work performed, 3 cubic millimetres (0·0000253 cubic inch per foot-pound) more oxygen is consumed, and 2·8 cubic millimetres of carbonic acid (0·0000236 cubic inches per foot-pound) produced. In order that respiration may be possible, the proportion of carbonic acid in the air breathed should not exceed 7·5 per cent., since, with this proportion, the throwing off of carbonic acid becomes impossible, even though there may be, at the same time, a surplus of oxygen. With 6 per cent. even of carbonic acid there is great difficulty in breathing, and fainting and muscular weakness occur. To remain any length of time in an irrespirable atmosphere it is not only necessary to be able to replace the oxygen consumed, but to avoid the enormous waste of oxygen which would take place if the expired air were thrown off into the irrespirable atmosphere, and to be able to make use of the oxygen contained in the respired breath by respiring into a closed vessel; and, in addition, in order to prevent a dangerous increase in the proportion of carbonic acid in the respired air, to make arrangements so that the carbonic acid contained in the respired air is absorbed as rapidly as possible.*

The length of time which apparatus constructed on the principle referred to will work depends, therefore, not alone on the supply of oxygen thereby provided, but very essentially on the quantity and exhaust efficiency of the reagents employed for the absorption of the carbonic acid. The nitrogen, originally in the air, in the closed vessel, and in the lungs, remains always unaffected, and goes in repeated successions through the cycle of expiration, revivification, and inhalation, after addition of oxygen. Further, no harm would ensue if the nitrogen completely disappeared, since, according to experience, pure oxygen can be breathed for a considerable time with complete immunity from any injurious results. On this point Dr. Gärtner said that:—

The breathing of undiluted oxygen, as medical experiments have proved, cannot hurt the human organism at all; on the contrary, its effect is refreshing and reviving. I have watched over several hundred oxygen inhalations carried out to cure the lungs, heart, and liver, and have myself repeatedly breathed pure oxygen four times with the apparatus here described—once uninterruptedly for 55 minutes—without once observing any symptom which could be regarded as a sign of injury to the organism.

* *Op. jam cit.*

Of the above-mentioned three appliances, the writer, considering the extremely favourable results obtained with it, proposes to describe more fully the pneumatophore and its uses, premising that the principal advantages of this apparatus over those of Mr. Schwan and Mr. Fleuss consist in its portability, diminished weight, constant readiness for use, and also the complete absence of valves and long passages for the respired and revivified air. A further essential factor in its superiority is that

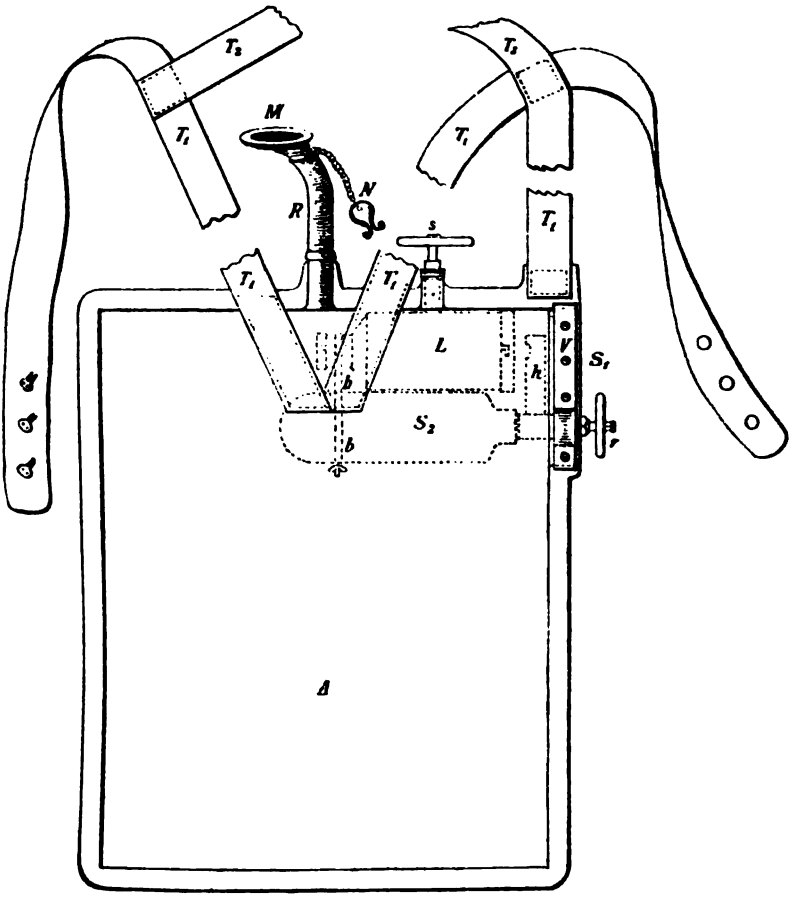


FIG. 1.

the reagents for the absorption of carbonic acid can be kept always in a fit and active condition for use, by keeping the apparatus in a closed glass vessel until immediately before use. Lastly, it may be stated, if the question of cost be considered at all in connexion with apparatus for such a purpose, that it is comparatively cheap compared with other appliances.

A short description of the pneumatophore by Dr. Fillunger appeared in the *Transactions* of The Federated Institution of Mining Engineers.* A detailed description is therefore scarcely called for here, and it may suffice to state that it consists essentially of an air-tight bag *A* (Fig. 1), which, as shown in Fig. 2, is carried over the chest. In the interior of the bag is a cylinder S_2, which contains, under a pressure of 100 atmospheres, 60 litres (3,660 cubic inches) of oxygen, a glass flask fitted in a metal cover containing a 25 per cent. solution of caustic soda, and a coarse barchent net or sponge, which, when the apparatus is in use, sucks up the soda solution when the latter is set free, and which is intended to offer a very large absorbing surface for the respired carbonic acid. *R* is a flexible tube provided with a mouthpiece, *M*, through which the user inhales the oxygen taken from the bag *A*, and through which the expired breath passes back into the bag. The whole is carried by the shoulder-straps *T*.

FIG. 2.

The manipulation of the apparatus is extremely simple: the bag is carried as shown in Fig. 2, and, on turning the screw *s*, the glass cylinder is broken, liberating the soda solution, which flows out of the metal cover and saturates the barchent net or sponge. The mouthpiece, *M*, is then placed within the mouth, and by slightly turning the screw *r*, oxygen is allowed slowly to escape into the bag, and lastly the nose-clip *N* is fitted on to the nose, closing the nostrils. The user is then quite prepared to enter the irrespirable atmosphere.

The length of time which the user thus prepared can remain in the irrespirable atmosphere depends on the physical exertion exercised by the user during the work of rescue. According to numerous trials carried out under the most difficult conditions, the duration of use varies from at least ½ hour, in the case of great exertion by the user, to 1½ hours when the exertion is less.

* Vol. xii., page 693.

The applicability of the pneumatophore has often been proved not merely experimentally, but in actual serious cases with the greatest success. Among the latter may be cited the case of two underground fires at the Shamrock colliery, Herne, Westphalia, where, owing to the carbonic acid and carbonic oxide given off by the fire, the atmosphere was quite irrespirable. The pneumatophore rendered indispensable and efficient service in the work of putting out the fires, whilst the Stolzo flexible-hose apparatus was useless, owing to the impossibility of placing the air-pump in a respirable atmosphere.* Numerous and most extensive trials made with ten pneumatophores at this colliery, with a specially trained rescue-corps, in artificially produced irrespirable atmospheres, will have a very special interest for mining engineers. To Mr. Th. A. Meyer, manager of the colliery, belongs the credit of designing a construction of the pneumatophore, which is specially adapted to permit of such work and operations in extinguishing fires as may require considerable time to be spent in an irrespirable atmosphere; and also of formulating many practical rules for the manipulation, and of making several essential improvements on the older construction of the pneumatophore.

Mr. Behrens' paper, already referred to, contains the results of the trials and operations with the pneumatophore at the Shamrock colliery, and it appears desirable here to refer more fully to his paper. As the first object of trials at the Shamrock colliery was to demonstrate the applicability and efficiency of the pneumatophore in the case of underground fires which recur with more or less regularity in the dickebank coal-seam, and as ½ hour even of the most exhausting labour appeared too short for effectually combating these fires, it was decided to make trials with the pneumatophore provided with two cylinders of oxygen, double the quantity, viz., 120 litres (7,320 cubic inches), in place of 60 litres (3,660 cubic inches). The trials, made under very difficult breathing conditions and in high temperatures in the close neighbourhood of the fire, proved that the supply sufficed for 60 minutes, whilst under less trying conditions the supply was sufficient for from 111 to 132 minutes. The oxygen-cylinders were fitted to be more conveniently carried on the back than on the chest, and the supply of oxygen was led from them to the breathing-bag carried on the chest, through hose-pipes passing over the shoulder. The use of the two cylinders appeared also to have the advantage that, on emptying the first vessel, the attention of the user was

* "Der von Walchersche Pneumatophor und Seine Verwendung in irrespirablen Gasenbeim Grubenbetriebe," by Mr. Behrens, *Glückauf*, 1897, vol. xxxiii., pages 949 to 957.

drawn to the fact that he had used half his supply; and he could then better estimate how much longer he could remain before it was desirable for him to return into an irrespirable atmosphere for a fresh supply of oxygen. A further important alteration was that the cylinder for the soda-solution was dispensed with as being unnecessary, and the useless weight saved. Corresponding to the increase in the supply of oxygen the amount of the soda-solution was increased from 425 to 1,100 cubic centimetres (26 to 67 cubic inches). The solution was poured into the breathing-bag through a funnel from the glass bottle in which it was stored. The barchent net in the breathing-bag for soaking up the solution was replaced by a sponge formed of fibres of cucurbitaceous plants (loofah), which offered a larger and better absorption-surface for the carbonic acid, and essentially facilitated breathing with the apparatus. Further, the carrying straps were removed from the chest and from under the arms, and in place of the vulcanite-mouthpiece a soft rubber-mouthpiece was provided. Lastly, for carrying the soda-solution to the working-place a closing knapsack was provided which, besides the bottle, carried a funnel for pouring the solution of soda into the bag, and a screw-plug. On arriving at the working-place, the knapsack with the bottle was unstrapped.

The Meyer construction of the pneumatophore, which is known as the Shamrock type, weighs 8·75 kilogrammes (19·2 lbs.), against 4·5 kilogrammes (9·9 lbs.) of the original apparatus. In spite of the not inconsiderable increase in the weight, it is unanimously asserted that, owing to the greater part of the weight being carried on the back instead of on the chest, the Shamrock type is easier to carry than the original type. Mr. Behrens states that the trials and work effected by the aid of the pneumatophore prove that it furnishes most effectual auxiliaries in the case of fire-damp and coal-dust explosions, where it is essential to be able to penetrate into an irrespirable atmosphere for the rescue of lives endangered by it.

Simple as is the construction of the pneumatophore, and easy as is its application, still the proper training of a staff in its uses is not only advisable, but essentially necessary. Above all, the user must accustom himself to a quiet and regular breathing with the apparatus, to a careful and sparing use of the oxygen, and to an occasionally necessary lifting and lowering of the breathing-bag.

As has been done at the Shamrock colliery and at a number of collieries in Austrian Silesia, the formation among the work-people of a colliery of a

rescue-brigade, who, as in the case of a fire-brigade or ambulance corps, are under strict discipline exercised in the use of the pneumatophore, is a step to be most urgently recommended. For every person a minimum time should be fixed in which he should be capable, under the most difficult conditions, of breathing with the pneumatophore, before he is definitely accepted as a member of the corps.

How much importance should be attached to the pneumatophore in the mining world can best be seen from the regulations of the Austrian Government of April 6th, 1897, in force in the Vienna inspection district for collieries of the Ostrau-Karwin coal-field, in case of fire-damp, coal-dust explosions, and of shaft fires. Rescue-appliances are prescribed which afford at least 1 hour's certain duration in an irrespirable atmosphere, and afford perfect freedom of movement to the user. The pneumatophore of Messrs. von Walcher-Uysdal and Gustav Gärtner is cited as an apparatus which fulfils these requirements, and for fire-damp collieries, the number of such apparatus to be provided is 5 per cent. of the total employees (including deputies, managers, and shot-firers), but at no colliery must there be less than 10 apparatus. Mr. Behrens considers that 10 apparatus will be sufficient even for the largest collieries, especially when provided with double oxygen-cylinders ; and he remarks that, in considering the number of apparatus to be provided, it should be borne in mind that it is much easier to train a rescue-corps of 10 members than one having 20 members, and that it appears better to provide a small corps thoroughly well trained than a larger corps less efficiently trained.

It is advisable, in addition to the pneumatophore, to provide an equal number of oxygen-cylinders, in order to be able to keep the apparatus properly filled at a moment's notice. Even then parts of the supply-cylinders are sent away to be filled. The filling of the small cylinders from the larger has, of course, the disadvantage that the pressure, and consequently the quantity filled into any cylinder, becomes less as more is taken from the larger cylinder. To provide against serious fire-damp or coal-dust disasters, it is advisable to keep 2 large steel cylinders, each containing 1,000 litres (35 cubic feet) of oxygen. Still more strongly to be recommended is the arrangement—as in the mining districts of Upper Silesia—of central stations, each for a number of neighbouring collieries, whence, in case of need, any desirable number of oxygen-cylinders and other rescue-apparatus could be immediately obtained.

It is evident that colliery disasters do not all occur to one pattern, but that each case may have its peculiarities, and each its own lesson. In all cases, however, the bringing out of the unconscious victims to fresh air,

or the bringing of the respirable atmosphere to them, stands first; and it is here that the pneumatophore takes its place as the most essential and valuable assistant. Dr. Haldane mentions, in the case of the explosions at Taylorstown, Micklefield, and Brancepeth collieries, that 77 per cent. of the fatalities were victims of the after-damp, in which carbon monoxide exercised the largest and most injurious influence. According to Dr. Haldane, the first definite symptoms of carbon monoxide poisoning occur when the blood contains 30 per cent. of this gas, with 50 per cent. paralysis sets in, and death occurs when 80 per cent. is reached. With 0·06 per cent. of carbon monoxide in the atmosphere, the percentage in the blood reaches 30 after 1½ hours in such an atmosphere, 0·10 per cent. in the atmosphere produces paralysis, and with 2 per cent. death occurs before the blood has had time to become saturated with the maximum of 80 per cent. in the blood, from which, under more gradual saturation, recovery may be still possible. After examination of the corpses, Dr. Haldane concluded that, although unconsciousness must rapidly have set in, a period from ½ to 1½ hours generally passed before death from carbon monoxide poisoning took place; and that, if it had been possible to have brought the victims during that time into fresh air, many of the lives would have been saved.

Consequently, it is evident how important is every minute of time within the first hour after the disaster, and an immediate search by rescue is urgently called for. For reviving the unconscious victims there is nothing so effectual as pure oxygen. According to Dr. Haldane, the removal of carbon monoxide from the blood proceeds five times as rapidly with pure oxygen as with fresh air. For this reason, the rescue-parties fitted with pneumatophores should therefore carry a supply of oxygen to administer to the victims, for which purpose rubber balloons appear most suitable. The oxygen is filled into these from the cylinders, and can thus be conveniently carried into the workings. The rubber balloons should be provided with a short flexible tube, having a small hard vulcanite tube at the end, which can be inserted in the nostrils rather than in the mouth, owing to the spasmodic biting and closing of the tube which occurs in case of a victim just returning to consciousness. The oxygen is forced through the nostrils by gentle pressure on the rubber balloon. How effectual the artificial inhalation of oxygen is will be evident from the following case cited by Mr. Behrens, where a workman was brought out from an underground fire in an unconscious state, and very shortly after breathing oxygen his eyes opened and the man was able to rise and walk away.

In December, 1896, four workmen were engaged smearing over the interior of a large steam-boiler with an anti-corrosive paint. Owing to vapours given off, these men became unconscious, without previously giving any call or warning to outsiders. In consequence of the stillness in the boiler, the attention of the latter was drawn to it, and one of them entered to ascertain the cause. As he did not return, a second workman was sent inside with the same results, so there were six persons unconscious in the boiler. Several hours had elapsed, when the works engineer came with two oxygen-cylinders, each containing about 1,000 litres (35 cubic feet), and these were emptied into the boiler. The difficult breathing of the unconscious men was immediately afterwards heard, and soon four of them crept out of the boiler. The other two remained still within the boiler, unconscious, jammed between the sides and internal flue. In order to bring the oxygen close into their neighbourhood, a flexible pipe was obtained, and a third cylinder of oxygen was emptied through this close to each of the men; and soon afterwards the two men recovered consciousness, and were able to creep out of the boiler. In spite of having been four hours in the poisonous atmosphere all the men recovered completely in a few days, and went about their work as usual.*

Mr. Garforth in his "Suggested Rules for the Recovery of Coal-mines after Explosion"† recommends that at least six oxygen cylinders should be kept at every large colliery. For considerable distances, where the disturbed state of the mine roadways makes it impossible to use corves or hand-stretchers, Mr. Rossner suggests the use of a board 4 to 6 feet long and 2 feet broad, with the front end rounded and provided with a guided draw-hook, and the sides provided with straps. The unconscious miner is quickly strapped to the board, which is used as a sledge, being drawn by one of the rescue-party and guided by the other. Where the roadways are not so much damaged, readier means can be provided. Not only for rescue-work, but also in the case of building stoppings, or repairing damaged ventilation-doors, the pneumatophore will be found useful. In all cases, however, it is of course necessary that a sufficient number of ready-filled apparatus should be on hand. With only one or even two apparatus in most serious cases it will be impossible to efficiently combat with the disaster.‡

* *Trans. Fed. Inst.*, vol. xiv., page 648. † *Ibid.*, vol. xiv., page 495.

‡ "On the use of Oxygen for Rescue Purposes," by Mr. Rossner, *Berg- und Hüttenmännische Zeitung*, 1897, pages 193-196.

An essential auxiliary to the pneumatophore is an electric lamp. For rescue-work, it is advisable that the lamp should be such that it can be carried about the body, so as to leave both hands free. The accumulators for the lamp are carried in a leather box or pocket specially provided. The lamp, which throws a very clear light, is fastened about the chest, so as not to incommode the wearer or prevent the free use of both hands. In the case of underground fires, erecting stoppings and dams, the recently-introduced White electric lamp can be recommended, which, besides giving a good light, is carried in the ordinary manner in the hand. It appears also advisable that a rescue-party should on their return leave lighted electric lamps and refreshments in the likeliest refuge-places on the way. After explosions, it is advisable that the rescue-party should also have with them an ordinary miner's safety-lamp. Where smoke is present, glass protectors for the eyes should be used, and as ordinary glasses will not suit all persons, it is advisable to use pneumatic protectors. As it is difficult to communicate with a rescue-party, it appears advisable to add as a complement to the pneumatophore and electric lamp, whistles of special construction to be blown by means of indiarubber-ball bellows, and to arrange a suitable system of calls or signals.

The writer hopes that, by the preceding suggestions, he may have succeeded in convincing the members that in the pneumatophore and compressed oxygen they have offered to them means for effectually combating and reducing the risks arising from fire-damp and coal-dust disasters, and of essentially diminishing the number of lives now sacrificed to the hostile elements that threaten the worker underground.

Although he sincerely hopes that such catastrophes as call for the aid of the auxiliaries which he has described may ever be remote from the experience of the members; still he must recommend that every mining engineer and official should make himself conversant with the duties which in some unlucky hour he may suddenly be called upon to undertake, and with apparatus which he will then look upon as an invaluable aid in the noble work of saving human life.

Since writing the above paper the writer's attention has been drawn to a respiratory apparatus introduced by Mr. J. Mayer, of Ostrau, and after repeated trials, he has come to the conclusion that it possesses considerable advantages over the pneumatophore. The writer proposes to write a report to the members on the results attained by the Mayer apparatus at an early date.

The CHAIRMAN (Mr. G. B. Walker) said that last year when in Westphalia he had visited the Shamrock colliery, and Mr. Behrens then stated that the pneumatophore had been invaluable in extinguishing gob-fires, and that he had organized a rescue-corps, who were available for working at gob-fires. Members would notice from the paper that the pneumatophore had been already adopted as a matter of obligation by the Austrian government in the mines of Silesia. The members were indebted to Mr. Cremer for his paper.

Mr. C. J. OLIVER (Chesterfield) asked whether any provision was made for the supply of oxygen to the rescued party.

The CHAIRMAN stated that the rescuing party must return and renew the oxygen-cylinder after half an hour, by opening the bag, and putting in a new oxygen-cylinder, or a reserve-cylinder might be taken.

Mr. CREMER then showed an apparatus consisting of a large india-rubber bag, with tube and nose-piece, for carrying the oxygen and supplying it to rescued persons.

Mr. MORGAN (Alfreton) asked whether the flexible tube and nose-piece could not be attached to the air-cylinder, instead of carrying the india-rubber bag.

The CHAIRMAN said that they had to mix the oxygen, just to supply the waste of oxygen in the air. The oxygen consumed and converted into carbonic acid was replaced by fresh oxygen, and the carbonic acid was taken up by the sponge.

Mr. MORGAN said that there was nothing special in the use of the indiarubber bag for supplying oxygen to the rescued, and suggested that the oxygen should be taken from the receiver instead of filling the bag.

The CHAIRMAN said that oxygen was put into the bag, as that in the cylinder was under too great pressure.

Mr. CREMER, replying to Mr. G. J. Binns, stated that the bag was lined with indiarubber, and that caustic soda had no action upon it.

Mr. BINNS asked whether he understood Mr. Cremer correctly to state that a man could breathe pure oxygen for a considerable time without danger.

Mr. CREMER stated that Dr. Gärtner said he had breathed pure oxygen for 55 minutes without once observing any symptoms which could be regarded as a sign of injury to the organism.

Mr. NASH asked whether having the bag in front was not a drawback, as there was a possibility of a man in climbing over a fall tearing the bag, and then the apparatus would become useless.

Mr. H. ST. JOHN DURNFORD (Ackton Hall colliery) said that the fact that the apparatus was used in Austria was the best proof of its value. There was no doubt that in the case of an explosion it might be used for 10 or 15 minutes and save men's lives.

Mr. R. TURNBULL (South Kirkby colliery) said that he had them in readiness for use at South Kirkby colliery. He had tried experiments and had had one on for nearly an hour, but had not put them to any practical use.

The CHAIRMAN said that there could not be the least doubt that in cases of colliery explosion, where the restoration of the ventilation was of the greatest importance, and where possibly the restoration of a stopping or the closing of a door might make all the difference between restoring the ventilation of a district and being unable to restore it (through not being able to reach the door on account of the gases to be encountered), the use of such a breathing-bag would enable a man to penetrate to that place and close the door or restore the stopping. Anyone who had had to battle with an explosion would know the immense value of being able to penetrate the foul air even for ½ hour at an early stage.

Mr. J. P. HOUFTON (Bolsover) believed, if this apparatus had been used by explorers at the Micklefield explosion, that more lives would have been saved, because 36 hours after the explosion had taken place a man was found breathing who might have been rescued, if it had been possible to have gone through the irrespirable atmosphere which drove them back. They tried, 6 or 8 hours after the explosion had taken place, to penetrate into this district, but it was found impossible; but an apparatus of this kind would have enabled them to go about in the choke-damp with impunity. There were a few falls, which would not have prevented them from going to the far end, and they would have found some of these men alive. After 12 or 15 hours, they got into one portion of the district, and 15 hours after the explosion, in one of the return airways, they found four or five men lying dead, but quite warm. If it had been possible to have got to them earlier, if oxygen could have been carried to them, and the means of getting them out, they would have been alive to-day. But while the apparatus might be of great value for that purpose, and for enabling the ventilation of the mine to be restored after it had been

disorganized by explosion, he was afraid no very hard work, such as clearing falls or filling stoppings, could be done with such an apparatus, as there would be considerable risk of damage to the bag.

Mr. H. St. John Durnford read the following "Notes on the Change in the Character of the Barnsley Coal-seam, between Rotherham and Pontefract":—

NOTES ON THE CHANGE IN THE CHARACTER OF THE BARNSLEY COAL-SEAM, BETWEEN ROTHERHAM AND PONTEFRACT.

By H. ST. JOHN DURNFORD.

There is no doubt that, even if the best part of the Barnsley coal-seam has not been already exhausted, there is not much of it left, and it would be hard to find in this country a finer seam of coal than the Barnsley coal-seam in the immediate neighbourhood of Wath-upon-Dearne. The writer does not propose to deal with the Barnsley coal-seam lying south of Rotherham, in which direction it gradually merges into the Top Hard coal-seam, and spreads over a great part of the counties of Derby and Nottingham; but will confine his remarks chiefly to the coal-seam existing between Pontefract and Rotherham, taking the line of the Swinton and Knottingley railway which runs practically north and south.

The southernmost section (Appendix, No. 1) is taken in the neighbourhood of Rawmarsh Church, and shows a seam altogether 8 feet 8 inches thick. The quality is very fine, but it is practically exhausted in this neighbourhood. A section (Appendix, No. 2) is also given from the Low Stubbin pit, not far from West Melton, between which point and the place where the previous section was taken an upthrow dyke to the north exists of about 270 feet.

The sections (Appendix, Nos. 3, 4 and 5) supplied by Mr. J. Thomson from the neighbourhood of Swinton and Wath-upon-Dearne, correspond very closely with that taken near West Melton, and over the whole of this area the clay-seam is practically non-existent, which adds very considerably to the value of the coal.

The writer proposes to deviate from the line from Rotherham to Pontefract to consider the seam as far as it has been proved in an easterly direction towards Doncaster, and would draw attention to the five sections (Appendix, Nos. 3, 4, 5, 6 and 7), No. 4 being taken in the neighbourhood of Mexboro' in the Manvers Main colliery workings, whilst Nos. 6 and 7 have been supplied by Mr. W. H. Chambers from Cadeby colliery.

It will be seen that, so far as it has been proved in an easterly direction, the seam fully maintains its character, and there is no dividing of the

disorganized by explosion, he was afraid no very hard work, such as clearing falls or filling stoppings, could be done with such an apparatus, as there would be considerable risk of damage to the bag.

Mr. H. St. John Durnford read the following "Notes on the Change in the Character of the Barnsley Coal-seam, between Rotherham and Pontefract":—

seen that the seam is slightly thinner than in some of the sections previously given, the workable portion of it underlying the bag coal amounting to 6 feet 2 inches. In this section it will be seen that the clay-seam makes its appearance for the first time as a separate seam, although it has not yet assumed a character totally different from that of coal.

A section is shown (Appendix, No. 9) of the coal at Hickleton Main colliery, which was taken last year at a point some 600 or 900 feet east of the pit. Two sections (Appendix, Nos. 9 and 10) are given from this colliery, and it will at once be seen that the clay seam has commenced to make itself objectionable. But the quality of the hard coal is little, if any, inferior to what it is at other collieries, and the inferior coal caused by the thickening of the clay seam is not sufficient to add much to the cost of production. Yet the fact cannot be overlooked that there is a certain amount of worthless material to be turned over, which in other places does not exist. The section (Appendix, No. 10) is taken at the northernmost point where the seam is at present being worked in what may be called its normal condition.

It will be noticed that a vast difference exists between No. 10 section and those kindly supplied by Mr. Turnbull from the workings at South Kirkby colliery (Appendix, Nos. 11, 12, 13 and 14). Between Bolton-on-Dearne and Moorthorpe some faulty ground apparently exists, but whether the seam changes its character all at once, or whether the change is gradual, has not yet been proved; the writer is, however, of opinion that the change is a gradual one, and this is to some extent borne out by the fact that the hard coal, both at South Kirkby and Monckton Main collieries, is of a good quality, and sells readily for steam coal, whilst further north, at Ackton Hall, Nostell and Hemsworth collieries, the hard coal is extremely thin and of indifferent quality.

The feature to be more particularly noticed, however, is the thickening out of the clay-seam beds; and it may be observed that at Monckton Main colliery (Appendix, Nos. 15, 16 and 17) it is only possible to work the lower portion of the seam, containing the hard coal, whilst at Ackton Hall colliery (Appendix, Nos. 19 and 20) the upper part of the seam has been worked for the last 8 or 10 years, but, unfortunately, the chief characteristic of the Barnsley coal-seam is entirely absent. Attempts have, however, recently been made, the writer hopes with some probability of success, to work the lower part of the seam containing the few inches of hard steam-coal that exists. The quality, however, still leaves a good deal to be desired; but there are evidences that it is likely to improve towards the south.

Both at Nostell (Appendix, No. 18) and Hemsworth, the Barnsley coal-seam, although proved, is practically untouched, and a very slight permanent improvement in trade would probably cause developments at these collieries. The northernmost point at which the Barnsley coal-seam—or Warren House, as it is called in this district—is worked is at Fryston colliery, and here again the seam is divided in very much the same manner as it is at Ackton Hall colliery.

Over the principal portion of the colliery district of West Yorkshire, as distinct from South Yorkshire, the Barnsley coal-seam is divided by a thickness of clod and shale varying from 8 to 18 feet, but, so far as the writer knows, in no one colliery are both these seams worked at one time. Doubtless, with the exhaustion of other seams in the district, attempts will be made to work either one or both of the seams which constitute the Barnsley bed. In no case, however, is the quality first rate, the best part of the seam, both at Ackton Hall, and at other collieries in the immediate neighbourhood being the 14 inches of top coal, which, owing to the extremely bad character of the roof above it, is to a large extent lost.

A boring has recently been put down, not far from the Midland and North Eastern Railway, near Pontefract, but so far as the writer has been able to ascertain, no definite information has been obtained. One thing only is evident, namely, that the seams here will be found at a considerable depth from the surface: the Barnsley bed probably lying at a depth of about 1,800 feet.

The writer hopes that these remarks on the change in character of the Barnsley coal-seam, which is, doubtless, better known to many members of the Institute than it is to himself, may be taken simply as an endeavour, on his part, to gather together information which may not be so readily accessible to everyone.

Finally, the writer would wish to express his thanks to the gentlemen who have supplied the various sections of the Barnsley coal-seam, and he would specially thank Mr. T. Newbould, Mr. J. T. Thomson, Mr. W. H. Chambers, Mr. Turnbull, and Mr. C. C. Ellison, for their courteous assistance.

APPENDIX.—Sections of the Barnsley Coal-seam.

Low Stubbin Colliery.

	No. 1, near Rawmarsh. Ft.	Ins.	Ft.	Ins.	No. 2, near Melton. Ft.	Ins.	Ft.	Ins.
Bag coal	1	6			1	0		
Top soft coal	1	6			1	3		
Hard coal	3	6			3	4		
Bottom soft coal	2	2			2	0		
			8	8			7	7

Manvers Main Colliery.

	No. 3, Swinton. Ft. Ins.	Ft. Ins.	No. 4, Mexboro'. Ft. Ins.	Ft. Ins.	No. 5, Wath-on-Dearne. Ft. Ins.	Ft. Ins.
Day coal	0 9		0 10		—	
Clod	2 2		0 1		—	
	—	2 11	—	0 11	—	—
Bag coal	1 2		1 4		1 1	
Top soft coal ...	1 3		1 6		1 2½	
Hard coal	3 0		3 4		3 3½	
Bottom soft coal ...	1 11		1 11		1 10½	
	—	7 4	—	8 1	—	7 5½

Cadeby Colliery.

	No. 6, West. Ft. Ins.	Ft. Ins.	No. 7, East. Ft. Ins.	Ft. Ins.
Day coal	1 4		0 11	
Bag dirt	0 7		0 7	
	—	1 11	—	1 6
Bag coal	1 5		1 3	
Top soft coal	1 5½		1 5	
Hard coal	3 3		2 10½	
Bottom soft coal	2 3½		1 11½	
	—	8 5	—	7 6

No. 8, Wath Main Colliery.

	Ft. Ins.	Ft. Ins.
Bag coal	1 1	
Top soft coal	1 2	
Clay coal	0 8	
Hard steam coal	2 6	
Bottom soft coal	1 10	
	—	7 3

Hickleton Main Colliery.

	No. 9, East District. Ft. Ins.	Ft. Ins.	No. 10, North. Ft. Ins.	Ft. Ins.
Bag coal	1 0		0 8	
Top soft coal	1 1		1 1	
Upper clay coal	1 4		1 2	
Dirt	0 1		0 1	
Clay coal	0 6		0 6	
Hard steam coal	2 3		2 2	
Bottom soft coal	2 3		2 4	
	—	8 6	—	8 0

South Kirkby Colliery.

	No. 11, South. Ft. Ins.	Ft. Ins.	No. 12, East. Ft. Ins.	Ft. Ins.	No. 13, West. Ft. Ins.	Ft. Ins.	No. 14, North. Ft. Ins.	Ft. Ins.
Top soft coal ...	2 10		3 0		2 11		3 1	
Dirt	1 1		2 0		1 3		2 3	
Clay coal ...	0 7		0 9		0 9		0 9	
Hard steam coal	1 8		1 9		2 0		2 1	
Bottom soft coal	1 11		2 0		2 0		2 3	
	—	8 1	—	9 6	—	8 11	—	10 5

MONCKTON MAIN COLLIERY.

	No. 15, East.		No. 16, at Shafts.		No. 17, North.	
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
Top soft coal ...	4 3		... 4 2		... 4 2	
Dirt	5 0		... 33 0		... 45 0	
Barnsley coal-seam	5 3		... 5 1		... 4 0	
	——	14 6	——	42 3	——	53 2

NOSTELL COLLIERY.

	No. 18.			No. 18 (continued).	
	Ft.	Ins.		Ft. Ins.	Ft. Ins.
Coal and bind	2	6	Coal	0	5½
Coal-shale	1	0	Strata	53	0
Coal	1	6	Coal, coarse ...	0	9
Spavin	1	4½	Coal, good	4	2
Coal	2	3½		——	68 11½
Spavin	1	11			

ACKTON HALL COLLIERY.

	No. 19.			No. 20.	
	Ft. Ins.	Ft. Ins.		Ft. Ins.	Ft. Ins.
Top coal	1 8		Top coal	1 2	
Dirt	0 11		Dirt	0 4	
Coal	1 2½		Coal	1 5	
Dirt	0 0½		Dirt	0 1	
Coal	0 2½		Coal	1 0	
Dirt	0 0½		Dirt and brassy coal ...	0 5	
Coal	0 8		Coal	1 6	
Coal, inferior ...	0 4		Clunch, etc.	10 11	
Coal	1 8		Barnsley coal-seam ...	3 2	
Strata	14 0			——	20 0
Barnsley coal-seam—					
Ft. Ins.					
Hard coal ... 0 8					
Soft coal ... 2 2					
Dirt and coal 0 6					
Soft coal ... 0 10					
——	4 2				
	——	24 11			

The CHAIRMAN moved a vote of thanks to Mr. Durnford for his paper, and the discussion was adjourned.

DISCUSSION UPON MR. E. B. WAIN'S PAPER ON "THE WORKMEN'S COMPENSATION ACT, 1897."*

Mr. G. J. BINNS (Netherseal colliery) thought that Mr. Wain held rather optimistic views as to the safeguards which they had with regard to the Workmen's Compensation Act: the safeguard in section 2, sub-section 1, appeared to his mind very slight. The Act said that notice should be given as soon as practicable after the accident, and before the

* *Trans. Fed. Inst.*, vol. xiv., page 354.

workman had voluntarily left his employment. That expression appeared to him very obscure, and conveyed nothing to his mind: if a man was injured he *ipso facto* left his employment. The same section appeared to contemplate a delay of six months in giving notice, and after so long a time it would be impossible to make a defence. It also provided that want of notice should not be a defence if such delay was caused by mistake or other reasonable cause; a plea which might be always set up. It appeared to him that this section, like the rest of the Act, provided ample work for the legal profession. It might not have occurred to all mine-owners that there were many different kinds of non-fatal accidents: three kinds which occurred at once. There was the accident which might be reported to the deputy, with the view of ceasing work or of not doing so if it did not become necessary; this was a class of accident which men met with sometimes, and which they reported for their own protection, in case they should have to go to the colliery club. (He enforced a strict rule that any man meeting with any accident should report it forthwith.) Many accidents were reported to the deputies, and entered in the books, which were never heard of again. In three days, at a small colliery drawing 700 tons, 12 accidents had been recorded in the report book, and one only was a case for medical attendance, while the other 11 returned to work next day. The second class consisted of accidents which required surgical attention, and necessitated a cessation of work, but they were not serious under the legal definition. The third class comprised those accidents reported to H.M. inspector of mines, and found in the Government statistics. Any one of these accidents might become a matter of claim, either as a permanent accident under the Workmen's Compensation Act or a fatality. They all had heard of accidents which had not been reported, but which had ended in death. Mr. Wain urged that every accident should be investigated, in case it should become a permanent disablement. In the Midland mines-inspection district, when H.M. inspector of mines asked that all accidents should be reported which had kept a man off work for seven days, the result was that in Mr. Stokes' report for 1896, they had three times as many non-fatal accidents reported as in 1894. He thought that the small accidents, which were never heard of now, might become a source of expense to colliery-owners under the Workmen's Compensation Act. As far as sections 12 and 13 of Schedule I. were concerned, they seemed to deal with permanent disablement, and gave power to commute the payments. One very important precaution was to keep a

book recording the average wages, and Mr. Wain suggested that all collieries should keep a wages-book in the form drafted by the central committee. Some collieries kept a wages-book and others kept none at all. He approved of the suggestion that a book should be kept on an uniform plan, showing the amount that each workman received, and he thought that members would find it pay in the end.

The CHAIRMAN thought that, in many respects, it would be absolutely impossible to protect owners against imposture. The more experience they had of the working of this Act the more they would find that imposture could be very successfully practised, more particularly in connexion with injuries which were not visible—sprains and internal injuries. He would strongly recommend that all owners should put in practice as soon as possible—he had already put it in practice for months past—the keeping of a record of all accidents, taking the time which they lasted, and debiting against the people who sustained the accident, the amount which would have been payable under the Act. One point required very serious and careful consideration, and that was the clause as to the serious and wilful misconduct of a person sustaining injury, for which his compensation was to be disallowed. That would, of course, depend on the interpretation which different County Court judges and assessors would place upon what constituted serious and wilful misconduct. For instance, to put a very simple case: where thin seams were worked, trammers were constantly in the habit of getting their fingers rubbed between the top of the tub and the roof, injuries which kept them at home for a week or two. Assuming that at a thin-seam colliery the proprietors supplied handles below the level of the top of the tub, and the officials insisted on trammers using the handles. It was certain that, if the handles were there, and a man got his fingers rubbed between his tub and the roof, he would get the injury through disregarding a specific order to use the handles at the tub-end. Therefore he should say that the man who wilfully preferred to put his hands on the top of the tub, rather than use the handles, wilfully injured himself. That, of course, was open to argument. It depended not upon what they thought, but upon what the judge thought. Then, again, they all knew in Yorkshire—he did not know whether it was so in Derbyshire—that trammers were not to go down gates in front of corves, but behind them. Managers enforced that rule as far as they could, but they knew that it was evaded. Supposing that they had done everything to prevent a man from going down in front of a tub, and a tub ran away and injured him for life, was it not his own

wilful and serious misconduct which had caused the accident? These were simple instances, familiar to everybody, and they could all add to them indefinitely. The Workmen's Compensation Act needed careful consideration, and in addition to merely recording accidents which occurred before June 30th, he thought that it would be desirable to note down their opinion, judging as fairly as they possibly could as to where and when accidents were caused by the wilful action of the workman himself. The maximum compensation was half a man's wages; but it did not follow that he should in all cases receive it. He should imagine that the question of contributory negligence, although swept away by the Act in one way, would weigh with the judge or referee in limiting the amount of compensation. For instance, if a man earning 26s. a week was entitled to 13s. a week, provided the accident was one which by no foresight he could have guarded against, surely if a man brought trouble upon himself to a certain extent by his own carelessness—if a man had been told to set props, and neglected to set them, and the roof fell on him and he was injured—it would be reasonable to suppose that the compensation would be reduced by his action, by his failure to do his part towards his own self-protection. Then there was the case where injury was caused to a workman by the direct action of another. For instance, if a workman struck a pick into another man, he was afraid that under the Act the workman who was so injured could sue his employer, and leave his employer to sue the other man.

Mr. Edward B. Wain wrote, he was afraid that he did not hold the optimistic opinion as to the value of the safeguards provided by the Act with which Mr. Binns had credited him. On the contrary, he had said that the employers' interests were only safeguarded to a slight extent, and his paper was written with the object more especially of calling attention to the necessity for taking every possible advantage of such safeguards as did exist.

As regards the notice of accident, he did not agree that it was, as had been stated in the discussion, necessary under the Act for the workmen to report the injury which might be the subject of claim before leaving the mine. The wording of the Act, "before the workman has voluntarily left the employment in which he was injured," appeared to indicate actual retirement from the service of a certain employer rather than a temporary cessation of work in consequence of accident. At the same time it seemed, in the case of mining accidents, to be absolutely

necessary that the injury should be reported immediately, or the rapidly changing circumstances and conditions of underground workings would prevent careful investigation, and the employer would consequently be prejudiced in his defence in any proceedings taken against him (section 2 (1) of the Act). Although the Act did not state explicitly that notice must be given in writing, there could be no doubt that a written notice was required. It had been held that notice required under similar conditions for the purpose of the Employers Liability Act must be in writing; and further, section 2 (2) of the Act could only be read as referring to written notice.

Although as had been suggested in the discussion, there was sure to be litigation as to what constituted "serious and wilful misconduct"—there was little doubt that all accidents directly or indirectly caused by breach, on the part of the injured person, of the General and Special Rules or of any regulations framed and published by the management, with a view to prevent accident, must come under this heading.

In several mining districts the colliery owners were joining in the formation of companies for the purpose of becoming their own insurers, and it seemed probable that the machinery for working the Act on the lines suggested in the paper as regards payment from a central office, inspection, etc., would be provided, and he felt sure that in such cases the working of the Act would not lead to unnecessary friction between master and workman. Whatever course was taken the greatest care would be necessary in the ascertainment of the earnings on which compensation was to be based. A County Court judge in the Midland district was credited with having said recently that when a miner came before him for compensation his earnings were given as 30s. to 35s. per week, but if the same class of men were sued in his court for small debts he then found that they pleaded that they were only working 3 days per week, and earning 3s. 4d. per day.

As regards the physical condition of persons employed, he thought that the employers would have no difficulty in getting a medical certificate of fitness in the case of any persons engaged after the passing of the Act. Although there was no provision in the Act for such examination before accident, it would be wise on the part of employers to see that they did not engage men who, from any physical infirmity, were more than usually liable to accident.

DISCUSSION ON MR. E. W. THIRKELL'S PAPER ON "ADEQUATE VENTILATION AND NOXIOUS GASES," ETC.*

Mr. THIRKELL wrote that in the hurry to get his paper ready, or through want of care, a clerical error had been made in the second paragraph of (I.) (*a*) page 390, where 0·04 had been taken as a divisor instead of 0·04 per cent., or 0·0004; this error had been carried throughout the paper into some of the other calculations, and he desired to correct the error before the discussion upon the paper was proceeded with. The corrections are as follows:—

The sentence commencing on line 18 of page 390 should read—"Ordinary air contains 0·04 per cent. of carbon dioxide, so that a man vitiates it to the extent of (21·76 cubic inches ÷ 0·0004 or) 54,400 cubic inches; consequently, 54,400 cubic inches of fresh air will be required to purify that vitiated, in addition to the 544 cubic inches required for breathing, or (54,400 + 544 or) 54,944 cubic inches per minute for ordinary breathing," etc.

The sentence commencing at the top of page 391 should read—"So that lying down being taken as unity, an ordinary day's work would be equal to about 32; and as a person at rest inhales 544 cubic inches per minute, when at work he would require (544 × 32 or) 17,408 cubic inches, which, added to the 54,944 cubic inches given above, makes a total of 72,352 cubic inches, or 41·87 cubic feet (say 42 cubic feet)."

The second sentence of the following paragraph should read—"A horse at rest therefore requires (12 × 250 cubic inches or) 3,000 cubic inches per minute for breathing, and of this 4·7 per cent. is carbon dioxide, or 141 cubic inches is converted into carbon dioxide, and this air will require (141 cubic inches ÷ 0·0004 or) 352,500 cubic inches per minute to purify it; a horse therefore requires 3,000 cubic inches for breathing, and 352,500 in addition to purify the air breathed, making 355,500 cubic inches altogether." For pit-horses, this quantity of air will be 338,625 cubic inches when working, or (195·95 cubic feet, say) 200 cubic feet per minute.

The sentence commencing on line 26 of page 391 should read:—"Then (163 cubic inches + 32·6 or) 195·6 cubic inches would be required per minute, of which 3 per cent. would be carbon dioxide or (195·6 cubic inches × 3 per cent. or) 5,686 cubic inches, and to restore

* *Trans. Fed. Inst.*, vol. xiii., page 389.

the air thus vitiated to its normal state would require (5·868 cubic inches ÷ 0·0004 or) 14,670 cubic inches; and (195·6 + 14,670 or) 14,865·6 cubic inches of fresh air or (8.6, say,) 9 cubic feet per minute."

The last paragraph on page 391 should read :—"It has thus been shown that a man at work requires 42 cubic feet, a pit-horse at work 200 cubic feet, and a lamp 9 cubic feet per minute for ordinary purposes."

The general conclusions on page 403 should read: The volume of air required for workmen, etc., is as follows :—

	Cubic Feet of Air per Minute.
Each person requires ordinarily when at work	42
Do. when in a working-place giving off ½ per cent. of gas	84
,, ,, ,, ¾ ,, ,, ...	105
,, ,, ,, 1 ,, ,, ...	126
,, ,, ,, 1¼ ,, ,, ...	142·8
,, ,, ,, 1½ ,, ,, ...	147
,, ,, ,, 1¾ ,, ,, ...	168
Each horse requires	200
Each safety-lamp requires	9
Each shot fired requires	500

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

AMIANTHUS-DEPOSITS OF VALLE MALENCO, ITALY.

Prime Contribuzioni allo Studio dei Giacimenti di Amianto della Valle Malenco. By LUIGI BRUGNATELLI. *Rivista di Mineralogia e Cristallografia italiana, vol. xviii., pages 44-54, with a figure in the text, Padua,* 1898.

The author, in the first place, describes a hydrated carbonate of magnesia, which he regards as probably a new mineral, associated with the amianthus-bearing rock. The specific gravity is 2·013, the chemical composition is :— $MgO = 43·32$, $CO_2 = 21·85$, $H_2O = 34·32$, and the author considers that the most probable chemical formula for the mineral is :—$Mg_3(HO)_2CO_3 + 3H_2O$. It occurs in extremely slender shining prisms, grouped in bundles intricately dovetailing into each other.

On a specimen of amianthus found at Lanzada, the white and slightly yellowish fibres of which are cemented together by magnesium carbonate, forming a sort of felt not unlike so called "mountain paper," crystals of magnesite, dolomite, and aragonite occur. With these are also associated minute crystals of titaniferous magnetite. The author points out the importance of the association of the three former minerals, especially also the fact that the carbonate of lime is in the aragonite condition, as this may serve to throw light on the mode of formation of the amianthus. He thinks it is demonstrable that the deposit was formed from the chrysotile variety of serpentine. L. L. B.

SYZRAN-PECHERSKOYÉ ASPHALT-DEPOSITS, RUSSIA.

Voyage géologique par la Volga de Kazan à Tzaritzyn. By A. P. PAVLOW. *Congrès géologique international : Guide des Excursions, No. XX., pages* 22-25, *with figure in text,* 1897.

These are worked on the right bank of the Volga, between Kashpur and Syzran, in the brecciated Permian limestone at one locality ; and in Carboniferous limestone at another locality, lower down the river. The scarcity or abundance of fossils, and the age of the rocks appear to have no connexion with the presence of the bitumen, for it is found also in Lower Callovian sands, which rest unconformably upon the Palæozoic limestones on the north of the Samara peninsula. The bitumen impregnates the mass of the limestone, and occurs in little accumulations and venules throughout the Carboniferous and Permian rocks in this area. It evidently percolated into the rocks from some external source, and spread through them more or less, according to their structure and permeability. As naphtha has been found on the left bank of the Volga, in the prolongation of the Jeguli Hills, that is, on the same line of dislocation as the bitumen-deposits, the author is inclined to believe that both asphalt and naphtha originally welled up from great depths through the fissures resulting from the dislocation.

[It may be added that, as regards means of transport, the asphalt-mines are exceptionally well situated, being in close proximity both to the great river Volga and to the Trans-Siberian railway.] L. L. B.

BERESOWITE, A NEW MINERAL.

Bérésowite, un nouveau minéral de Béresowsk en Oural. By J. SAMSILOW. *Bulletin de la Société Impériale des Naturalistes de Moscou*, 1897, *pages* 290-291.

This mineral occurs in small flakes, but never in distinct crystals, is of a dark red colour, has perfect cleavage, and a specific gravity of 6·69. Three analyses were made, and show percentages of lead oxide varying from 79·24 to 79·36, of chromic acid 17·93, and carbon dioxide 2·46, whence the author derives the chemical formula: $2PbO, 3PbCrO_4, PbCO_3$. When the mineral is found in association with galena it is always separated from the latter by a layer of cerussite. Beresowite also occurs in pseudomorphs after crocoïte. L. L. B.

THE GROTTAU BROWN-COAL DEPOSIT, NORTH BOHEMIA.

Die Grottauer Braunkohlenablagerung in Nordböhmen. By DR. FRIEDRICH KATZER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1897, *vol. xlv.*, *pages* 561-564.

This little known field is situated in the valley of the Neisse, near Grottau. The deposit belongs to the older Miocene period, and forms an offshoot from the great Zittau basin. At the present time, it is worked by means of the Franz and the Christianen shafts, the former of which is 102 feet (31 metres) deep, whilst the latter does not go lower than 62 feet (18·9 metres). The Franz shaft traverses 19 seams of coal, most of them less than 40 inches (1 metre) in thickness, though there is one seam 25 feet (7·7 metres) thick; and the entire thickness of coal exceeds 50 feet (15½ metres), of which 31 feet (9·55 metres) is worked as the main seam. In the second shaft there are 10 seams of coal, 4 of which average 40 to 48 inches (1·00 to 1·20 metres) each, and the remainder range between 20 and 36 inches (0·5 to 0·9 metre), the total thickness of coal being 28 feet (8·75 metres).

The deposit constitutes a semi-basin, the western portion (Franz shaft) of which is more extensive than the other, and is in a less disturbed condition, the coal-strata being nearly horizontal and almost free from faults; whereas in the eastern section (Christianen shaft) faults and distortions are frequent, and the stratification is broken up to a considerable extent. Many of the faults are open for a width of 20 inches and a depth of 16 to 20 feet (5 to 6 metres), and the walls are covered with effloresced sulphates derived from the pyrites associated with the coal.

The coal is of a brownish colour, and contains a number of stems and other remains of fossilized wood, as also occasional clusters of soft dark coal apparently derived from soft vegetable matter. It can be readily ignited, and burns with a bright though smoky flame. The specific gravity averages 1·163; calorific power (Berthelot) 3·972 calories; and the chemical composition of the coal when dried at 110 Cent. is: carbon, 53·22; hydrogen, 5·56; ash, 3·27; oxygen, nitrogen, etc., 37·95. In its natural state the coal contains about 55 per cent. of moisture, and as it retains this somewhat tenaciously, it is generally sold by measure. The presence of sulphur—as much as 3·8 per cent.—lowers the value of this coal for domestic use.

Owing to the distortions of the seams, mining is rather difficult, especially in the Christianen shaft, and the amount of coal often falls as low as 10 per cent. of the total quantity of matter raised. Pit fires—due either to spontaneous ignition brought about by the oxidation of pyrites, or to direct absorption of oxygen by the coal—are frequent, but bricking up the burning portions is of little use, the best remedy being to bring about a fall.

Four grades of coal are sorted: flat blocks up to 40 inches square; middles — lumps about 20 inches in diameter; nubbles up to 4 inches; and siftings. The dust is used up at the mine. The total output, amounting to some 725,000 bushels (300,000 hectolitres) per annum, meets with a ready sale, so that the coal is not exposed to the deterioration (desiccation) consequent on prolonged storage. To save the expense of packing the seams, the owners prefer to buy the land and allow the surface to subside as the seams are worked out. C. S.

THE DONETZ BASIN, RUSSIA.

Le Bassin du Donetz. *By* TH. TSCHERNYSCHEW *and* L. LOUTOUGUIN. *Congrès géologique international: Guide des Excursions, No. XVI., pages* 1-55, *with figures in the text and* 2 *plates*, 1897.

The area to which this name is generally understood to apply is that portion of Southern Russia which is overspread by Carboniferous deposits of the littoral type, presenting frequent changes of facies in the vertical succession, and containing coal-seams. Hitherto mining operations have been more particularly concentrated on the western part of this area; its greatest length is about 240 miles from east to west, and its greatest breadth about 100 miles from north to south. On the south-west the area touches the vast sheet of granite of the districts of Berdiansk and Mariupol. The base of the Carboniferous deposits is made up of a series of Upper Devonian felspathic grits, conglomerates, and quartzites, with green and red clay-slates and porphyritic breccias. The last-named are intimately connected with a great mass of porphyry, which separates the above-mentioned rocks from a series of dark-grey limestones and shales. Very detailed descriptive sections of the Carboniferous strata are given by the authors, commencing with the barren Lower Carboniferous Limestones. Above these come micaceous grits, in which thin coal-seams begin to make their appearance. These are succeeded by shales, grits again, and limestones. One of the features of the Carboniferous group in the Donetz basin is the frequent intercalation of limestones among the grits and shales; it is true that the calcareous beds are not of great thickness, rarely attaining 25 feet, but they show a remarkable constancy in the general characters and fauna of each horizon over a large area. The result is that the coal-seams of the Donetz basin are in every locality easily recognized and correlated with those of other localities, with a precision and ease scarcely paralleled elsewhere in Europe. It seems as if the Donetz had been the south-western gulf of a vast Palæozoic sea wherein the Carboniferous sediments were laid down.

The Middle Carboniferous group begins with a succession of sandstones, shales, and dark-brown and light-grey limestones. Above these comes a coal-bearing series, but the seams are seldom thick enough to repay working. Then follows a rapid alternation of shales, limestones, and sandstones, amid which are coal-seams varying in thickness from 1 to 3 feet, seldom thicker. They are very actively worked in the Kalmius river-basin, where the so-called Smolianinovsky group yields coking coal, gas coal, and semi-anthracitic coal. Then there is the anthracitic Bokovskaia group, the coals of which are generally semi-anthracites, less frequently pure anthracites. The coal is found to become a coking coal in certain areas where the continuous outcrop of Coal-measures comes into contact with the Cretaceous strata. At Uspenskoye is worked the Yonovskaia group, which includes no less than eight workable seams.

Above these comes a series of strata about 1,100 feet thick, with many thin seams, but scarcely one that is workable. This is overlain by another 1,000 feet of shales, limestones, etc., much richer in coal, with seams, one of which is about

40 inches thick. The sixth division, in ascending order, of the Middle Carboniferous, that is, its uppermost portion, is about 1,000 feet thick at the typical locality, Lissichansk. The number of coal-seams and the relation of their total thickness to that of the associated rocks are such as to make this division the most profitable to work in the whole series. The seams vary from 10 inches to 6 feet or more in thickness.

The Upper Carboniferous group is about 7,000 feet thick, and workable coal-seams are found only in its lower portion. The succession is again one of limestones, shales, and sandstones many times repeated (lithologically). The uppermost strata are clay-slates, with concretions of argillaceous sphærosiderite resting upon a thin, light-grey, highly fossiliferous limestone.

Folding and faulting are observed throughout the area; indeed, the only strata which do not appear to have been dislocated are the Tertiaries. In the northern part of the basin, near the contact with the Cretaceous, the folds in the Carboniferous are smaller, but sharper, and more complicated by faults than elsewhere. Mining operations have also revealed much evidence of thrust-planes. The authors believe the coal to be of drift origin, and not derived from the decay of vegetation *in situ*, as in so many instances the roof of the seams is formed of shale or limestone containing an abundant marine fauna.

Other minerals of industrial importance, besides coal, occur in the Carboniferous of the Donetz basin—such as gold, mercury, silver, zinc, lead, and iron.

The auriferous deposits, discovered only in 1893, are in the territory of the Don Cossacks, along the Nagolny-Kriaj hills. Here micaceous grits of varying thickness alternate with grey clay-slates, they show distinct anticlinal folding, and are traversed by a series of nearly vertical parallel quartz-reefs, ranging from a few inches to 10 feet in thickness. In the portion nearest the surface, native gold is found, diminishes in quantity lower down, then increases again deep down in conjunction with a ferruginous so-called "chalcedony." The reefs are largely mineralized with brown iron-ore and pyrites, and contain a few inclusions of galena and blende. Working in these deposits is still in the preliminary stage.

Along the same hill-range are grouped the silver, zinc, and lead-mines. A great many were shut down after a few years' unsuccessful working, but in 1890 that of Nagolnaia was re-opened, and a large mine was started near Nagolchik. The rocks are, in every respect, analogous to the auriferous country-rock.

The iron ores are associated exclusively with limestones which crop out on the surface, and down to a depth of about 30 feet, the limestone is found to have passed into a brown spathose ore. But, both as regards quantity and quality, this ore offers little prospect of playing any considerable part in the rapidly developing industries of Southern Russia.

At Nikitovka, on the Kursk-Kharkov-Azov Railway, are the cinnabar-deposits discovered in 1879. The ore occurs in grits and quartzites, much fissured and faulted. If a transverse section be taken of a metalliferous reef, the ore is found distributed in an irregular network, corresponding to the number of fissures which traverse the grit and quartzite. Among the latter are intercalated blocks of coal, within which are found well-formed crystals of cinnabar. It would appear as if the coal had acted as a "concentrator" of the metalliferous substances. The ore must have been deposited from solutions percolating through the fissures in the rocks. A detailed description is given of the tectonic structure, as seen in the mine: there are several shafts here, and levels are mentioned of 120 feet or more below ground.

The Carboniferous series is succeeded by Permo-Carboniferous shales, limestones, and red and green sandstones containing here and there copper ore. Above

these come the dolomites of the Lower Permian. Now, at Bakhmut, these dolomites rest on yellowish-grey clays and marls which contain deposits of gypsum, anhydrite, and rock-salt. In 1874, borings carried down to a depth of 660 feet proved nine beds of salt, of a total thickness of 300 feet. Hereabouts was opened the Briantzevka mine, worked by a French company nowadays: its broad galleries are lighted by electricity. Other mines are the Novaia Velichka, Charlamovka, Peter the Great, etc. The yearly salt production now reaches 258,000 tons (16,000,000 pouds) or more, and is one of the most important industrial features of the Donetz district. L. L. B.

TKWIBULI COAL-FIELD, CAUCASUS.

Excursion à Tkwibouli. *By* S. SIMONOWICH. *Congrès géologique international: Guide des Excursions, No. XXVa, pages* 1-5, *with figures in the text,* 1897.

This short paper is preceded by a complete bibliography of the subject, and the lie of the strata is shown in four horizontal sections. On the northern slope of the Lagori ridge, at 1,500 feet above sea-level, the Tkwibuli river, flowing in many places over outcrops of coal, divides into two branches, which disappear for a time underground in the Cretaceous limestones. After a subterranean course of about 3 miles they reappear on the other side of the escarpment, and continue their course under different names into the plain of Colchis. In the lower part of this river-basin, beneath the Cretaceous limestone appear variegated clays, and these in turn are underlain by sandstones containing *Pecopteris exilis* and coal-seams. Near the village of Kursebi are two seams divided by a micaceous grit, dipping 12 degrees south-west. The lower seam is the thinner of the two; the upper proved at a depth of 70 feet, is 30 inches thick. It yields a fairly compact, non-caking coal; this shows on analysis:—

Coke, 74·70 per cent.	Carbon, 38·30 per cent.	Water,	5·40 per cent.
	Ash. 35·75 ,,	Volatile matter,	20·55 ,,

Below the coal-bearing sandstones comes a great thickness of Liassic shales, which form the central part of the basin. These are much folded, and form at the foot of the Nakeral Mountain the base of the coal-deposit proper of Tkwibuli. Here the total thickness of the coal-seams, and intercalated grits and carbonaceous shales, is about 65 feet. Tho following analysis of the Tkwibuli coal is quoted from Prof. E. Favre:—Water, 1·9 per cent., ash, 8·5 per cent., and calories, 62·4. The Lias and the coal-bearing beds dipping northward, disappear under the Nakeral Mountain. It is said that spathose iron-ore was at one time worked within the mass of the coal itself, in the Lamchreli or Kedur area. The plants found in the coal-bearing beds are of Stonesfield Slate (Oolitic) age. L. L. B.

COAL-FIELDS AND IRON-ORES OF SHANTUNG, CHINA.

Der geologische Bau von Schantung (Kiautschou), mit besonderer Berücksichtigung der nutzbaren Lagerstätten. *By* FERDINAND VON RICHTHOFEN. *Zeitschrift für praktische Geologie,* 1898, *pages* 73-84, *with maps and sections in the text.*

The distinguished Under-secretary for Colonial Affairs of the German Empire, the author of this paper, is wellknown for his travels in the Chinese Empire and for the great book and atlas in which he embodied the results of his observations. No person, therefore, was better qualified to point out to the German people the economic advantages and the mineral wealth of their new colony at Kiaochau.

The mountainous, deep-bayed peninsula of Shantung is divided by a fault-line running north and south, and sensibly parallel with the course of the Wei Ho, into two geologically and orographically distinct parts. In the eastern region, a broad area of depression stretches from Kiaochau Bay away to the northern coast of the peninsula. It is a fertile, undulating, thickly populated country, with a soil not alluvial, but made up of decomposed rock *in situ*.

The westernmost half of the province of Shantung belongs to the Great Plain of China, and is covered by fluviatile deposits from the Hoang Ho and other rivers and by wind-blown loess.

In Northern China, all the Palæozoic strata, from the Cambrian upwards, lie undisturbed, whereas in Southern China all these, the Carboniferous included, are bent up into folds. Now, Shantung partakes of the northern type. On a rock-base of ancient gneisses and granites are superposed crystalline schists and limestones, 10,000 to 15,000 feet in thickness. Great denudation in pre-Cambrian times has reduced these outcrops to mere sporadic patches, and the ores associated with them have given rise to many delusive hopes. Galena and copper-ores were observed among these rocks by the author, but not in paying quantities.

Talc and steatite occur in the crystalline limestone, and the last-named mineral is largely worked for ornaments and images. The highly-disturbed quartzites and sandstone of Changshan in Western Shantung belong doubtless to the Upper Archæan Wutai series: they are overlain by undisturbed Cambrian.

A characteristic occurrence in Eastern Shantung is the rapakivi-like "Korea granite," which forms whole hill-ranges; it is much veined by pegmatite and quartz, the former of which is rich in tourmaline.

Upon the folded Archæan rest the equivalents of the Cambrian, the middle portion of which is especially developed in Shantung. These middle Cambrians consist of quartz-sandstones, red clay-slates, and siliceous limestones. The "globulitic limestones," full of little dark ferruginous spherules, probably of organic origin, furnish a good building-stone. Above these come again red clay-slates, followed by the Carboniferous series, without any intercalation of Silurian or Devonian.

The Carboniferous Limestone forms here the lowest member of the system. It is overlain by argillaceous and arenaceous rocks, with the uppermost of which are associated porphyries and porphyry-tuffs (probably of Permian age). These in Shantung are immediately followed by loess: Tertiary and Mesozoic strata being conspicuous by their absence.

The coal-fields are restricted to the eastern side of the fault-line already mentioned: they contain several seams of good quality and workable thickness. In part, the Coal-measures are interbedded with Carboniferous Limestone and clastic rocks, in part with the latter alone, and in part, too, with rocks which appear to be of a later age than Carboniferous. Going from west to east, the most important coal-fields are those of:

(1) *Po-Shan.*—Very extensively worked. In quantity and quality of coal, and in the great industrial demand for the mineral, this field takes the first place. On the northern edge of the hill-range, is situated the busy chief town of the district: glass-ware, pottery, enamel-glaze, and paints are manufactured here. The Hi Shan or Black Mountain, south of the town, is the mining centre of this region; and the two chief pits (near the pottery village of Kutawan), are worked by circular shafts, 15 feet in diameter, and respectively 200 and 260 feet deep. The lower shaft is very wet, and here, haulage is done by mules. In the upper shaft, it is done by a windlass worked by 12 to 15 men. The coal is loaded into bags

of oxhide, and the production is said to have averaged at one time 60 to 80 tons per day. The seams vary between 6 and 8 feet in thickness. Timber is the one great desideratum in this district.

(2) *Chang Kiu.*—This coal-field lies 30 miles east of the provincial capital Tsi Nan Fu, and the same distance north-west of Po-Shan. Seams 4 and 6 feet in thickness were worked here at one time, and the author thinks that boring operations would reveal extensive deposits of workable coal.

(3) *Wei Hsien.*—The locality of this name is an ancient commercial centre for Northern Shantung and the meeting-point of many routes of traffic. Its importance may be expected to increase concurrently with the development of Kiaochau.

The coal-outcrops lie south of the city in a sort of "bay" that cuts into the mountain-chain: east and west are volcanic tuffs which probably mark a further extension of the Coal-measures: the strata dip gently northward.

The last mine worked in this neighbourhood was shut down because of the difficulty found in contending with the water: the seam 3 to 4 feet thick was worked by a shaft about 150 feet deep. About 1,000 tons of coal lay on the pit-heap, not coking, somewhat pyritous in character. There are many other abandoned shafts round about, and three seams have been traced at different levels. Much small coal and dust was got, due perhaps to the shallowness of the workings. The low angle of dip and the number of the seams promise a rich reward to those who will undertake deep-level mining.

(4) *I Chu Fu and I Hsien.*—These coal-fields, in contradistinction to the others so far mentioned, lie on the south side of the chief mountain-range. Excellent coking coal is found in association with Carboniferous Limestone and shales rich in hæmatite; coal-seams occur at seven points in the horizontal section described in detail by the author, and iron ore at three points. This is probably due to repetition of the strata by faulting. Workings have not been carried on at deep levels, on account of the inflow of water. A mandarin persuaded a European engineer to set up pumping apparatus at one locality, but the pipes were ordered of too small a diameter, and, moreover, the mandarin committed suicide when the victorious Japanese marched into Wei-hai-Wei. European methods of deep-level working can alone place this district in its true position, in the forefront of the mining industry of Shantung.

The iron ores (red and brown hæmatite) are not worked. All the raw iron needed is brought from the province of Shan Si, and is smelted together with scrap iron in the foundries of Shantung, producing an excellent metal.

Magnetite, due to contact-metamorphism by diorite-dykes and sills, is found in association with crystalline limestone, epidote and felspar-rocks east of Tsi Nan Fu.

The author concludes with a long panegyric of the favourable situation of Kiaochau, especially as the starting-point of railways into the interior, and as a shipping-harbour for the chief coal-fields of China. L. L. B.

PRODUCTION OF ALCOHOL FROM THE GASES OF COKE-OVENS.

Ueber die Gewinnung von Alkohol aus Koksofengasen. ANON. *Glückauf*, 1897, *vol. xxxiii., page* 800.

Dr. P. Fritzsche (*Chem. Ind.*, vol. xx., pages 226-271) has experimented upon the production of alcohol from the ethane contained in the gases given off from coke-ovens, in accordance with the method of Prof. Faraday and Prof. Hennel, which consists in treating ethane with sulphuric acid and water.

Coke-oven gases contain 1 to 1·8 per cent. of ethane, and the writer found that this could readily be absorbed by sulphuric acid upon a working scale, and that the apparatus required would be no larger than that used for absorbing benzol from these gases. To produce 1 gallon of alcohol—4·85 lbs. of ethyl-sulphuric acid 35 lbs. of concentrated sulphuric acid, and 50 lbs. of water are required. The removal of ethylene, after the benzol has been got rid of, presents no difficulties. Of the 45 lbs. of concentrated sulphuric acid required to produce 1 gallon of alcohol, 40 are returned to the next operation.

At the present uncommonly low prices of alcohol, it is doubtful whether this method of manufacturing it would pay. H. L.

DETERMINATION OF SULPHUR IN COAL AND COKE.

Ueber die Menge von Schwefel, die beim Vercoaksen von Kohlen im Coaks verbleibt und die Menge von Schwefel, die bei diesem Processe entweicht. *By* C. v. JOHN. *Verhandlungen der k.k. geologischen Reichsanstalt, Vienna*, 1897, *pages* 134-137.

The author examined several varieties of coal with a view to determining the part played by sulphur in the process of coking. He began with an ordinary analysis of the coal, wherein, besides determining the percentage of water and ash, the calorific power was determined according to the Berthier method. He admits that the Berthier test can hardly be termed scientific, and that it can only yield approximate results; but he points out that, when applied under similar conditions to different coals, this test is valuable for purposes of comparison.

The sulphur in the coal was determined according to the Eschka method, as amended by Prof. Fresenius. This consists in ignition with a mixture composed of 2 parts of caustic magnesia and 1 part of sodium carbonate, the argillaceous material being extracted with hot water to which a solution of bromine was added till the liquid assumed a pale yellow tinge. This was then poured through a filter, and the sulphur (precipitated by means of barium chloride) was ultimately estimated as barium sulphate, the filtrate having been previously treated with hydrochloric acid and boiled till the whole of the bromine was eliminated.

The amount of sulphur thus found is the total amount present in the coal, and this the author, for convenience, terms the "total sulphur." Exactly the same method was followed for determining the amount of sulphur present in the coke: moreover, the quantity of sulphur left in the ash, both of coal and coke, was determined. The difference between the "total sulphur" and the proportion of sulphur present in the ash represents the amount of combustible or so-called "injurious sulphur." In some cases, the last-named was determined direct by burning the coal or coke in a stream of oxygen, and passing the products of combustion through bromium hydrochloride. This and the tarry products of distillation absorbed all the sulphur given off on combustion. The results obtained by the foregoing direct method invariably coincided with those calculated from the difference between "total sulphur" and "ash sulphur."

In order to institute a direct comparison between the "total sulphur" in a given coal, and that in the coke produced from it, a percentage of the sulphur in the coal was calculated corresponding to the percentage of the coke produced. By this means it was easy to see how much sulphur was got rid of in the process of coking. Also, the percentage of combustible sulphur in the coal and the percentage of combustible sulphur in the coke got from 100 parts of the same coal were determined.

An elaborate table of results accompanies the paper, from which it is seen that the geologically older coals lose less sulphur in coking than the brown coals. The presence of pyrites as such was proved in very few coals: in most case, especially in the brown coals, sulphur occurred in the form of organic compounds. No general law as to the ash-sulphur can be deduced from the results.

Ten of the coals examined were from various Coal-measure localities in Austro-Hungary; one was from the British Coal-measures; seven were Tertiary (brown) coals from Austria, Rumania, etc., and one was a specimen of recent peat. The percentage of "total sulphur" in coal varied from 0·19 to 8·84; in coke from 0·26 to 7·25; of sulphur in coal-ash, from 0·01 to 1·49, in coke-ash from 0·01 to 2·05; of "combustible" or "injurious sulphur" in coal from 0·18 to 7·77, in coke from 0·05 to 4·08. The percentage of "injurious sulphur" got rid of in the coking process varied from 22·58 to 72·22. L. L. B.

QUANTITATIVE ANALYSIS OF COMMERCIAL COPPER.

Ueber die Quantitative Analyse des Werk-Kupfers. *By* E. MURMAN. *Monatsheft für Chemie*, 1896, *vol. xvii.*, *pages* 697-731.

The Sub-Sulphide Method.—The copper (1·2 to 1·5 grammes) being dissolved in dilute warm nitric acid, a few drops of hydrochloric acid, and sulphuric acid in excess, are added, and the solution evaporated to drive off the nitric acid, the silver and lead precipitated being then filtered off and washed with acidified (H_2SO_4) water, and the copper thrown down as sub-sulphide. If a little sulphuretted hydrogen be mixed with the hydrogen employed for the ignition-process, the time-limit and temperature of the operation are less restricted than when pure hydrogen is used, but the results are higher unless a bright red heat is maintained all the time. The best method is to employ pure hydrogen for the first quarter of an hour, repeating the heating until constant weight is obtained, and finally adding a little sulphur and heating up again to a dark-red heat.

To free the sulphide precipitate from alkalis (in the reagents), it should be heated in an air-oven, and washed with dilute sulphuretted-hydrogen solution before heating to redness. Lime is more difficult to get rid of, but this impurity is of almost inappreciable amount. Silica is left behind on dissolving the precipitate in nitric acid after weighing.

The electrolytic determination is hardly reliable, owing to the variations (3 to 4 milligrammes) in the weighing of the platinum basin, and to the presence of water. This may be avoided by heating to redness, which, however, causes inconvenience from the formation of copper-platinum alloy at the plane of contact.

Oxygen.—The sample is freed from fat by the aid of a solvent, and then dried and brightened with a cloth and some clean sand. After weighing, the metal is heated in an atmosphere of hydrogen in a tube 10 inches (25 centimetres) long, $\frac{3}{5}$ to $\frac{1}{2}$ inch (10 to 12 millimetres) in diameter, with a strong bulb 2 inches (5 centimetres in diameter), for between one and two hours (according to the thickness of the sample cuttings) at a bright red heat, and afterwards for a further half hour, the oxygen being determined by the loss in weight sustained by the copper.

Lead.—The cold solution of the metal in nitric or sulphuric acid is treated with a little sulphuretted hydrogen, all the lead being precipitated along with the first copper thrown down; by dissolving the precipitate in nitric acid and subjecting it to electrolysis the lead is separated from the accompanying copper. This method is much more delicate than precipitation as sulphate.

Arsenic and Antimony. A large sample is heated in hydrogen for over two hours at a bright red heat, the upper part of the bulb being capped with asbestos to prevent condensation of the antimony. This will, however, take place to some extent in the tube, the greatest portion being arrested by passing through hydrochloric acid and bromine. In weighing the antimony as oxide, the alkalis should be dissolved out by water after the first heating, and since the oxide volatilizes at red heat only in a reducing atmosphere, air should be admitted to the crucible during the ignition.

Cuprous oxide, if present in quantity, is determined by the argentic nitrate method, though this is not sufficiently accurate to be used when the percentage is small. C. S.

ELECTROLYTIC ANALYSIS OF COPPER FOR TECHNICAL PURPOSES: ESTIMATION OF ARSENIC, ANTIMONY, SULPHUR, ETC.

Analyse du Cuivre industriel par Voie électrolytique. *By* A. HOLLARD. *Comptes rendus de l'Académie des Sciences*, 1896, *vol. cxxiii.*, *pages* 1063-1065.

Estimation of Arsenic and Antimony.—The residual liquor from the electrolytic deposition of the copper is evaporated to near dryness, taken up with 1 to 2 cubic centimetres of hydrochloric acid, and made up to 200 cubic centimetres, being then treated with hydrogen sulphide at an initial temperature of 70° to 75° Cent. until cold, and filtered at the end of 24 hours. The precipitate, which consists of arsenic, antimony, a little lead, and possibly copper, is washed with hydrogen sulphide solution, and treated with ammonium sulphide and filtered, the solution being evaporated to dryness, warmed with hydrochloric acid and potassium chlorate, and treated with ammonia and magnesia mixture to throw down the arsenic, which is re-dissolved in acid and precipitated once more by ammonia. Antimony is thrown down from the acidified ammoniacal liquor as sulphide, and re-dissolved in strong alkaline sodium sulphide, to be finally deposited by means of a 0·18 ampère current, the volume of liquid not to exceed 80 cubic centimetres, on account of the small quantity of antimony present.

Estimation of Nickel, Cobalt, and Iron.—The filtrate is heated to drive off hydrogen sulphide, the iron being peroxidized by nitric acid and the liquid evaporated until sulphuric acid fumes are evolved. On re-dissolving in water, the iron is precipitated by a slight excess of ammonia, the precipitate being freed from nickel and cobalt by dissolving in sulphuric acid, then re-precipitated and titrated with permanganate, ammonium sulphate being added to the filtrate, from which the nickel and cobalt are deposited by a 0·48 ampère current.

Silver is estimated from the electrolysed copper, or, if in small proportion, from a fresh (10 to 50 grammes) sample, by solution in nitric acid, precipitation as silver chloride, which is purified by re-precipitation, and electrolysed from solution in potassium cyanide.

Lead is determined from a separate sample (10 grammes) dissolved in a large volume of nitric acid, and precipitated as hydrated dioxide of lead (PbO_2) by a 0·3 ampère current, the oxide being de-hydrated by heating to 120° Cent. for half-an-hour.

Sulphur.—From 5 to 20 grammes of the copper are dissolved by nitro-hydrochloric acid and the sulphur determined therein by the usual method.

C. S.

FORMATION OF THE DIAMOND DEPOSITS OF SOUTH AFRICA.

Zur Theorie der Diamantlagerstätten in Südafrika. *By* Dr. GEORG GÜRICH. *Zeitschrift für Praktische Geologie,* 1897, *pages* 145-148.

As is wellknown, the diamond deposits of Kimberley consist of vertical, slightly conical pipes approximately circular in cross section; their walls show vertical striations. They lie in an approximately straight line. The blue ground that fills them consists of a serpentinous cement containing numerous inclusions of the same serpentinous substance, variously coloured, and fragments of numerous minerals and rock-masses. The latter are known as boulders, or when very large, as floating reefs; they consist of fragments of the enclosing rocks of the Karoo formation, mostly of diabase and amygdaloid; there are also fragments of rocks belonging to the deeper-lying Cape formation, and of a cherzolitic rock containing olivine, pyroxene, and other minerals. The most plentiful mineral inclusions are olivine, pyroxene, garnet (pyrope), iron pyrites, and diamond, the latter forming 0·000,002,5 to 0·000,050 per cent. of the whole. All the minerals occur frequently in fragments, except the pyrites, which always form uninjured crystals. The contents of each pipe are split up into a number of vertical columns of somewhat different petrological habitus, separated from each other by thin fissures, filled partly with calcspar and other minerals. The richness of these columns in diamonds is also variable.

The author agrees with Prof. Daubrée's opinion, that the pipes are funnels formed by explosive action, which forced upwards the magma; he suggests that several partial explosions may have united simultaneously to form the grand explosion, and that contraction on cooling produced afterwards the various columns [his explanation is, however, far from intelligible, H. L.]. Basing his opinion on Prof. Moissan's experiments, he holds that the carbon was contained in the basic magma in the form of metallic carbides, and that the carbon separated out from these under great pressure in the form of diamonds.

The occurrence of the vents in a south-south-east and north-north-west line indicates that the first cause of the fission was tectonic, and the deposits were therefore formed during one and the same epoch. The fissure thus formed allowed water to penetrate to the basic magma, and the explosion may have been due to the vapour thus generated, or its violence may have been increased by the gases produced by the action of water upon the metallic carbides.

As regards the age of the deposits, they are naturally more recent than the Kimberley shales, whilst they are parallel to the western edge of the Continent, along which Cretaceous rocks are deposited; hence it may be concluded that the tectonic action to which these north-north-west lines are due was pre-Cretaceous.

H. L.

RECENT EARTHQUAKES IN BOHEMIA.

Einige Bemerkungen zu dem Erdbeben von Graslitz, vom 25 October bis 7 November, 1897. *By* F. E. SUESS. *Verhandlungen der k.k. geologischen Reichsanstalt, Vienna,* 1897, *pages* 325-328.

The first feeble shocks took place at Graslitz and Bleistadt in north-western Bohemia, between 2 and 3 a.m. on October 25th, 1897, frequent shocks taking place during the following days, till on October 29th a period of great seismic disturbance set in, violent shocks succeeding each other from 6·24 a.m. on that day until 8·42 a.m. on October 30th. Shocks of diminishing intensity continued

more or less till November 6th, when another period of great disturbance set in, culminating in an extremely violent shock on November 7th, at 5 a.m. After-shocks made themselves felt on various dates up to November 16th.

The area over which the earthquake extended increased in a ratio coincident with the increase in violence of the shocks. It was recorded at localities far into Saxony and Bavaria, as well as in Bohemia, and great stress is laid on the fact, that it was not the first (October 25th) but the second and third series (October 29th and November 7th) of shocks that were the most violent.

In the copper-mines at Schwaderbach, which are worked in very fissile slates, the shocks were very much felt, and several falls of rock took place. The seismic epicentrum lay just between this locality and Graslitz, a fact which helps to account for the especial intensity of the earthquake here.

The author points out that this earthquake, in all probability, belongs to the group of tectonic earth-movements described by Prof. H. Credner in former years as the Erzgebirge-Vogtland group, and the centre of disturbance is gradually shifting along a north-and-south line. L. L. B.

EARTHQUAKE AT AIDIN, ASIA MINOR.

Sulla Velocità di Propagazione del Terremoto d'Aidin (Asia Minor) del 19 *agosto* 1895. *By* G. AGAMENNONE. *Atti della Reale Accademia dei Lincei, Rendiconti*, 1898, *series* 5, *vol. vii., pages* 67-73.

Of this earthquake, the author gave a detailed account in Dr. Gerland's *Beiträge zur Geophysik*, vol. iii., part 3, Leipzig, 1897 ; and the chief object of the present paper is to emphasize the velocity and wide area of propagation of earth-shocks.

The movement was most intense along the valley of the Meander, reaching the degree ix.-x. (of the De Rossi-Forel conventional scale) at the epicentrum, which was a little east of Aidin in lat. N. 37° 51′ and long. E. of Greenwich 27° 55′. The violence of the shock was so great that it was very plainly felt along the western coast of Asia Minor, also 60 miles north and 60 miles south of the epicentrum, and 120 miles east of it. The seismic waves perturbed the micro-seismograph in far-off Padua and the horizontal pendulum in still more remote Strasburg, localities some 1,200 to 1,500 miles away from the epicentrum.

Reducing the time at each locality to a common standard, Constantinople mean time, the author finds that the first shocks travelled to Padua at the rate of 6 miles a second, and to Strasburg at the rate of about 2 miles a second, and the maximum shocks at the respective rates of 2 miles and 1½ miles per second. The great discrepancy between the figures for Padua and Strasburg as regards the first rapid shocks may be in part due to the fact that those which began to disturb the seismograph at the former place were too feeble to disturb visibly the horizontal pendulum at the latter. This instrument, however, began to record the less rapid but more violent shocks, and the commencing shocks of Strasburg were no doubt the same as the maximum shocks of Padua.

The data thus obtained appear to throw doubt on the value of Prof. Cancani's theory of longitudinal and transverse waves, from which hitherto the bases of calculation of the distance of the epicentrum from the point of observation have been derived. The author admits, however, the association with every great earthquake of slow transverse oscillations similar to the great undulations of the ocean, but their velocity has no connexion with that of the longitudinal vibrations postulated by the Cancani theory. L. L. B.

CENTRAL CONDENSATION-PLANT.

Die Central-Kondensation der Zeche Ewald bei Herten. *By* FR. KOEPE. *Glückauf*, 1896, *vol. xxxii., pages* 838-841, *and plate.*

The modern method of applying the condensing principle to colliery-engines consists, not in providing each separate engine with an independent condenser, but in constructing a common condensing-plant into which several engines may exhaust. The plant consists of a surface-condenser, cooled by means of draught induced by a chimney; its object is to condense the exhaust steam by means of mine-waters that are useless for steam-raising purposes, and to return the condensed water to the boiler-feed. The advantages secured are: an economy of coal of 25 to 30 per cent. by the vacuum in the engine; a further economy of about 5 per cent. of coal by the avoidance of incrustations in the boilers; an economy of water of about 424 to 565 cubic feet per hour; economy in boiler-cleaning and boiler-repairs, combined with a higher degree of safety; and economy in the first cost of the boilers.

The plant consists of a condenser, with cooler and chimney, and of pumps. The condenser is formed by a large receiver, from which pass six sets of brass tubes, each pair of which is in communication. A stream of mine-water runs down over the receiver and tubes: the whole plant standing under the chimney so as to be constantly kept cool by the induced air-current. The cooler consists of a series of inclined planes arranged step-wise one below the other, over which the water used to condense the steam has to pass, whereby it is cooled down and can be used over again. The boiler feed-pump is arranged to take the condensed water from the warmest part, whilst the air-pump draws air that has been cooled as much as possible. The circulating-pump is an Encke rotating-pump. The condensed water is filtered to remove any lubricating oil it may contain.

This plant has been in operation since the beginning of June 1896. The vacuum is 85 to 90 per cent., the temperature of the external air being 25° to 30° Cent., that of the air from the air-pump 30° to 32° Cent., and that of the condensed water 48° to 50° Cent. The average coal-consumption in the last four months of working without condensing was 5·26 per cent. of the output, and in the first three months, with the condenser in operation, 4·34 per cent., although only about two-thirds of the engine-power of the colliery are at present connected to the condenser. The saving in coal, realized as above, is calculated at £1,260 per annum, together with a saving in the cost of water, hitherto purchased, of £350, so that the total annual saving amounts to £1,610.

The condensing-plant is constructed to take 22,000 lbs. of steam per hour, but will suffice for 26,500. Its total cost, including pipes and foundations, was £4,000, but against this must be set the saving of at least two boilers, costing £1,250, that would otherwise have been required, so that the first cost will be recouped in about 18 months' working. H. L.

EXPLOSIONS IN AIR-COMPRESSORS.

Explosionen an Luftkompressoren. *By* FERD. STRNAD. *Glückauf*, 1897, *vol. xxxiii., page* 789, *and* 7 *illustrations.*

At the works of Messrs. L. A. Riedingen, Limited, in Augsburg, an experimental air-compressor has been in operation for a good many years; it is a belt-driven compressor, with a cylinder 6·9 inches in diameter, 13¾ inches stroke, working at 132 revolutions per minute; the valve-gear consists of a circular (revolving) slide-valve, which serves both cylinder-ends. The valve-chest lies underneath the cylinder, and is connected with it by means of two long, narrow

passages. The cylinder body, the upper part of the long narrow ports, and the upper portion of the valve-chest are externally cooled by means of water, the rest of the valve-chest and the cylinder-ends only by exposure to the atmosphere. Lubrication is effected by means of a lubricator fixed on top of, and in the centre of the compressor; the oil trickling down is distributed by the movement of the piston over the inner surface of the cylinder, and thence passes through the long, narrow ports into the valve-chest.

Various lubricating-oils were tested in this compressor, and especially valvoline oils, which are especially prepared for resisting high temperatures. It was found that with such oil of the highest quality, mixed with a little petroleum, the compressor would continue to work uninterruptedly as long as the gauge-pressure did not exceed 5 atmospheres. When it rose, however, to 7 to 8 atmospheres, it was noticed that in a few days the inspiration of air became gradually less and less, and finally ceased altogether. The valve continued to move regularly, but no air was drawn in.

Upon opening the compressor, it was found that the long narrow passages or ports between the cylinder and the valve were completely filled with the decomposed lubricant, which formed so firmly coherent a mass that it had to be removed by means of a scraper, and in places even by hammer and chisel. When ordinary machine-oil was used, the ports became stopped up in from 5 to 12 days, the length of time affording a very sensitive test for the quality of the oil. This rapid decomposition of the oil cannot be due to high speeds, as the piston speed is only about 295 feet per minute, and similar compressors, but with independent circular valves, one for either cylinder end, have worked quite successfully at 7 to 8 atmospheres. The obvious conclusion is that the fault lies with the long narrow ports. The deposit is caused either by the heat generated in the cylinder during the compression, or else by the oil which can trickle down the sides of the cooled cylinder being decomposed by the heated walls of the ports; possibly both actions occur together. In proportion as the deposit forms and the area of the ports is decreased, the pressures during compression must rise, attended by a simultaneous increase of temperature. Long narrow S-shaped passages, such as are usual in air-compressors, should accordingly be avoided.

It is also advisable that the entrance of the compressed air into the receiver and its exit should not both be at the top of the receiver, but one at the top and the other at the bottom, so that the contents of the receiver may be continually swept out, and no opportunity given for the accumulation of explosive oil-gas.

As the formation of such gas in air-compressors can never be quite avoided, the following precautions should be observed for the sake of preventing explosions:—

1. No pockets should exist in the air-conduit.

2. If it is desired to compress to more than 3 to 4 atmospheres, compound (stage) compressors should be employed.

3. If a single-stage compressor has to be used, it should have short ports and independent valve-motion for each end of the cylinder; in other cases, only so much oil should be introduced into the cylinder as will suffice for its lubrication, the valves being lubricated independently. Of the various types of valve, slide-valves are preferable, because they admit of a much greater speed of revolution.

4. If, for the sake of economy, a single-stage fast-running compressor is employed, it is absolutely necessary to clean it thoroughly and at regular intervals.

5. The surface-cooling of the compressor should be as effective as possible; nothing, however, is gained by cooling the exterior of the valve-chest unless the valve-faces themselves can be cooled. H. L.

EXPLOSION OF AN AIR-COMPRESSOR AT DORTMUND (WESTPHALIA).

Explosion eines Luft-kompressors auf der Zeche Kaiserstuhl I bei Dortmund. ANON. *Glückauf*, 1897, *vol. xxxiii., pages* 503-506, *and plan.*

An explosion took place on April 30th, 1896, in the air-compressing plant at the Kaiserstuhl I pit of the Westphalia colliery at Dortmund, which was attended with serious consequences. The air-compressor was contained in a massive two-storied building; the receiver was situated close to it, and it was surrounded by the other buildings that formed the surface-plant of the colliery. The compressor was on the Burkhardt and Weiss system, with twin slide-valves, with cylinders 23·6 inches in diameter and 31·5 inches stroke. It was cooled externally by water circulating round both the body and ends of the cylinders; the valve-chests were not cooled. The steam-cylinders were 26·4 inches in diameter, the steam-pressure was 6 atmospheres at the boilers, and the mean working speed was 32 revolutions per minute. The compressed air was conducted by cast-iron pipes, 9·5 inches in diameter and 0·75 inch thick, to the wrought-iron receiver, 7 feet 2 inches in diameter and some 33 feet in length; the latter was provided with two safety-valves, set to blow off at 4½ atmospheres. There was no valve between the compressor and the reservoir.

The air taken into the compressor was freed from dust by filtration through cotton-wool; the valves and air-cylinders were lubricated with an oil bought under the name of *valvoline*, and said to possess a high igniting-point. The valves were lubricated automatically.

The explosion took place about 6·30 a.m., accompanied by a most violent detonation; dense fumes rose from the building, the roof of which had been blown off, whilst all inflammable materials inside it were set on fire. Much damage was done to the building, though the compressor-cylinders suffered but little; but the valve-chests, 1·2 inches in thickness, were blown off. The interior of the cylinders, the valves, and the remains of the valve-chest were covered with a black greasy coating, which was solid in places and showed signs of incipient coking. A sootlike and more or less firm crust was also found lining the air-pipes.

The air-receiver had completely disappeared, its site being covered with a heap of bricks, tiles, and rubbish; it had been completely blown to pieces, one fragment over 1 cwt. in weight being found a mile away, whilst the largest piece, weighing 76 cwts., was thrown clear over a building 100 feet in height.

The origin of the explosion is indicated by the fact that a sootlike body was found coating parts of the interior of the machine, and this could only be produced by the lubricating oil employed. The temperature of the valve-chest must have been sufficiently high to decompose this oil, generating gases which, mixed with compressed air at a high pressure, formed a most violent explosive mixture.

As the cause of the explosion had to be sought in the lubricating oil employed, it was considered advisable to have the latter tested at the Berlin Royal Chemico-Technical Institute. The report stated that the valvoline oil submitted must be designated a good lubricant; its density was 0·89 at 15° Cent.; it was free from animal and vegetable oils, and consisted of hydrocarbons that had taken up but little oxygen. The flashing-point in the open crucible was 291° Cent., its boiling point 375° Cent. These figures indicate that care had been used in its manufacture. When such oils are dropped into red hot retorts they are decomposed, gaseous products and a coke-like residue being formed; in this way 20 grammes of the lubricating oil can convert 1 cubic metre of air into an explosive mixture. There are no lubricating oils that are incapable of being decomposed by heat with the formation of combustible gases.

The considerable quantity of residue found in the valve-chest shows that, in spite of the high character of the oil, considerable quantities of it had been decomposed. The prime cause of the accident must therefore be ascribed to the defective cooling of the valve-chests.

Several explosions of similar nature, but of very trifling character, have occurred in the Dortmund mining district. Although an explosion of so serious a character as the one here described is quite exceptional, and must be ascribed to the accidental coincidence of a number of contributing circumstances, it nevertheless demonstrates that in compressers fitted with slide-valves the greatest attention must be bestowed on the quality of the lubricant, upon the most efficient system possible of cooling the valves, and upon keeping them clean and free from oil-residues and particles of coal-dust. H. L.

EXPLOSION OF FIRE-DAMP IN THE ROCK-SALT MINES AT AKNA-SZLATINA, HUNGARY.

Eine Grubengasexplosion im Steinsalzwerke zu Akna-Szlatina in Ungarn. *By* L. LITSCHAUER. *Glückauf*, 1896, *vol. xxxii.*, *pages* 935-936.

At Akna-Szlatina, a deposit of rock-salt 2,200 metres (7,218 feet) in length, 1,700 metres (5,577 feet) in width, and of still unknown depth, has been worked from a very remote period. The mine is greatly troubled with water, which makes its way in, under considerable pressure, from subterranean reservoirs. An attempt had been made to tap these by means of levels, one of which had for some time past penetrated into the zone of solution by this water. The cavities thus formed were filled, to a depth of 6 to 8 inches, by a layer of bituminous mud. As fans were kept continuously at work, no one suspected that this would prove a source of danger, so that naked lights were everywhere used. On August 28th, 1896, however, an explosion took place in this part of the mine, by which two miners were hurt severely and one slightly, followed a couple of hours later by a second explosion that killed two miners, who were examining, by means of naked lights, the workings where the first explosion had taken place. It is supposed that gas was forced into the mine by the sudden collapse of cavities, dissolved out as before mentioned. H. L.

EXPLOSION IN THE RESCHITZA PITS ON DECEMBER 18TH, 1896.

Die Grubenkatastrophe in Reschitza am 18 *Dezember*, 1896. *By* ROBERT LAMPRECHT. *Glückauf*, 1897, *vol. xxxiii.*, *pages* 21-24.

The Reschitza collieries are situated about 2 miles south of Reschitza in Southern Hungary. The coal occurs in basins of crystalline schists, in which the Lias formation has been deposited, and which are greatly faulted, disturbed, and folded. There are two workable coal-seams intercalated between sandstones; their thickness varies from 1·5 to 3 metres (5 to 10 feet), and they are separated by a distance of 40 metres (131 feet). The general strike is east to west, and the dip 30 to 70 degrees south. There are two main shafts, the Szecsen 460 metres (1,510 feet) deep, and the Almasy 390 metres (1,280 feet) deep, situated 700 metres (2,300 feet) to the west of the former. A day-drift 2,250 metres (7,382 feet) long, fitted with an electric railway, is used to run the coal out. There are six working-levels below the day-drift in the Szecsen shaft and five in the Almasy shaft. The latter is ventilated by a Pelzer fan, 2·5 metres (8 feet) in diameter. The Szecsen shaft acts

as an intake, a Guibal fan of 9 metres (29 feet 6 inches) in diameter, and 2 metres (6 feet 6 inches) wide being erected close to the mouth of the day-drift, and connected with it by means of a fan-drift. The air is brought through the levels running parallel to the strike, and returns by a return-air drift, driven 6 metres (20 feet) higher up. The mine is so gassy that stentings have to be driven to connect the two drifts about every 10 metres (33 feet). The pillars are worked by overhand stoping.

The explosion occurred at 6·30 p.m. on December 18th, 1896, when there were 128 men in the pit in the back-shift. A huge column of flame shot out from the downcast shaft, set the timbering of the shaft and the wooden poppet-heads on fire, destroyed the doors, windows, and roof of the engine-house, and killed two men who were at the pit-head. Out of all the men in the shaft only 34 were saved.

The explosion is supposed to have originated at the westerly face of the main north level of the Szecsen pit in the top seam, which had been driven for a length of 90 metres (295 feet) from the crosscut to the shaft, which was itself 420 metres (1,377 feet) in length. At this spot, the coal was very hard. The air in the face had been tested by a deputy before the accident by means of a Wolf benzine safety-lamp and 1½ per cent. of gas had been found; the place was nearly free from dust. In the afternoon, the firemen had fired two dynamite shots electrically in this place. The water-gauge up to the time of the explosion was pretty steady at 5·5 millimetres (2·16 inches), but it dropped on an average twice in the hour down to 20 millimetres (0·79 inches), this fall being due to the opening of the doors in the day-drift for the passage of the sets of tubs. At the time of the explosion, the water-gauge rose to 90 millimetres (3·5 inches) owing to the effect of the blazing shaft, the direction of the ventilation being thereby reversed.

There seems little doubt that the explosion was caused by a safety-lamp, which may either have been damaged, or forced open, or may, on its relighting by the existing percussion-ignition, which works upwards inside the lamp, have forced the burning gases out of the lamp.

H. L.

BRUNNER COLLIERY EXPLOSION, NEW ZEALAND.

(1) *Report of Royal Commission appointed to inquire into the Brunner Coal-mine Disaster on March 26th, 1896.*

The coal-face where the explosion occurred is 4,584 feet distant from the adit entrance. The main drive rises for a distance of 1,914 feet from the coal-face, the remaining 2,670 feet to the adit being driven on the level. The area of the mine is about 200 acres, the thickness of the coal-seam varying from 7 to 10 feet. The coal is highly bituminous, yielding from 12,000 to 15,000 cubic feet of gas per ton. Fire-damp had occasionally been met with, but no serious accident had ever occurred. The texture of the coal is compact in the solid, but somewhat tender and friable when mined; it is moderately moist, and does not readily form a heavy deposit of light dust. All the witnesses agreed that the mine could not be considered as fiery, and could not be classed as dry and dusty. The ventilation is effected by a Schiele fan producing from 16,000 to 18,000 cubic feet of air per minute. The coal is worked on the board-and-pillar system.

The explosion occurred about 9·25 a.m. on March 26th, 1896, killing all workmen in the mine, numbering 65 persons.

The mine was worked by open lights, except on a few occasions, when safety-lamps were ordered to be used in certain parts. At the time of the accident open lights were used throughout the mine, with three exceptions, where Marsaut lamps were employed. The explosive used was blasting-powder. The explosion was caused by a blown-out powder-shot, fired by a person unknown, contrary to the rules of the mine. The flame ignited the fire-damp evolved from the surrounding coal, which in turn ignited the coal-dust raised by the concussion of the shot. It was assumed that the explosion was locally intensified by small quantities of fire-damp. There was no direct evidence that the explosion was commenced by the ignition of an accumulation of fire-damp.

There was no evidence of working-tools being found at the place, and as there was no holing or undercutting it was assumed that an old shot-hole, drilled some ten months previously, had been used. An estimate of the coked coal-dust in the mine resulting from the explosion showed that 12,000 to 15,000 cubic feet of gas had been liberated.

Three days were occupied before the rescuing party were able to reach the workings, owing in a great measure to the presence of carbon monoxide gas or white-damp.

Owing to the soft nature of the floor and the hard nature of the roof, brick-stoppings could not be built, and the method adopted was "crib-logging," consisting of two walls of heavy timber, the intervening space being filled with stones and dirt. This method was considered very satisfactory.

The following suggestions are made for the better working of coal-mines:—No inspector of mines should be appointed who has not qualified by examination and practice as a colliery manager; every inspector should have a safety-lamp capable of testing ½ per cent. of gas; an inspector, after visiting a mine, should place a copy of his report on the pit-heap. Underviewers, deputies, or foremen should be required to pass an examination before the inspector of mines, and, if qualified, receive a certificate. A. C. K.

(2) *On the Brunner Mine Disaster.* *By* Sir James Hector. *Transactions and Proceedings of the New Zealand Institute*, 1896, *vol. xxix., page* 602.

The writer states, as evidence of the terrific effects of the explosion, that the smoke came to the outlet against the draught to the workings; that the coal was charred over a very large area to a depth of 4 inches; and that the body of one man was driven up an incline of 300 feet and smashed against the wall of coal. At the top of the incline (at the motor-house), a man was smashed to pulp and a boy stripped of every particle of his clothing without being burned in the slightest degree. The explosion was, it was conclusively proved, not of fire-damp, but an imperfect explosion of coal-gas, leaving white-damp—the most deadly of all damps, ½ per cent. of which would be fatal if continuously breathed.

The explosion may have been caused by a miner putting in a large charge of blasting-powder in an imperfect manner, so that instead of breaking down the coal it blew out like a cannon-shot and so caused the explosion.

The evidence at the inquest showed that this noxious gas arose from imperfect combustion, and was carbon monoxide, or white-damp, and that the foolish conduct of the person who fired the shot had been the cause of the disaster. The author mentions that a flameless explosive was used at the Kaitangata mine, and it had proved most successful. M. W. B.

THE COAL-DUST QUESTION.

(1.) *Procédés employés pour combattre les Poussières dans les Mines de Houille.* ANON. *L'Industrie*, 1897, *page* 165.

All the methods employed for counteracting the effect of dust (besides its removal) have the object of rendering it damp, and may be classed under five categories, accordingly as they depend on the use of sea-salt or other hygroscopical substances, steam, damped surfaces, water-carts, or water-pipes laid throughout the workings. A saline solution may be efficaceous, if the results of experience in towns near the sea be considered applicable to mines.

It is acknowledged that damped surfaces produce a good effect by moistening the air-current, which thus has less tendency to dry the dust, while in some cases they may assist the ventilation. The advisability of damping at intervals portions of the workings is recognized; and in the Saar district the regulations require that a length of 164 feet (50 metres) of workings between two districts shall be rendered moist. If the downcast shaft be damp, the entering air will be saturated with water while the ventilation will be assisted. At the Planitz mine, in Saxony, the air-current passes across a wooden paddle-wheel partly dipping into water,

Most of the methods adopted, or at any rate known, in Great Britain are described, and dismissed with the observation that they all have their advantages, but that no one of them appears susceptible of general application, while an excellent precaution consists in watering the bodies of the tubs before they leave the working-places.

At the Hibernia colliery, near Gelsenkirchen, Westphalia, a method of watering the coal-dust has been adopted, which the Mine Administration has lately made obligatory in all the seams of this colliery. The water required is stored in a lodge of 19,494 cubic feet (552 cubic metres) capacity, formed by an old cross-cut, arriving clarified by passing through a filter-bed 6 feet 6 inches (2 metres) thick, and is distributed in the workings by a system of pipes 150,333 feet (45,820 metres) long and of three different diameters, the smallest being 1 inch (26 millimetres) in diameter. The pipes are of galvanized wrought-iron in 16½ feet (5 metres) lengths, with flanges for connexion. Every 164 feet (50 metres), and also at the end of each branch, there is a stand-pipe with cock and screw-union, their total number being 1,016. The sprinkling is effected with hose-pipes screwed on to the stand-pipes and terminating in nozzles of ⅛ inch (3 millimetres) diameter, partly by the miners and partly by 13 men specially appointed for the purpose. The cost of laying, extending, maintaining and working the system from July 1st, 1890, to June 1st, 1895, amounted for materials to £4,816 (96,319 marks), and for wages to £4,124 (82,480 marks), forming a total of £8,940 (nearly 178,800 marks); and the cost for materials and wages during 1894 amounted to £2,577 (51,550 marks). J. W. P.

(2) *La Question des Poussières de Charbon.* *By* ARMAND HALLEUX. *Bulletin de l'Association des Ingénieurs de Liége*, 1896, *vol. xx., page* 12.

Inasmuch as it is an acknowledged fact that an atmosphere, free from fire-damp, but charged with fine coal-dust, is explosive, there is every reason to search for and study the physical and chemical factors which intervene in rendering coal-dust more or less dangerous. The physical characteristics, however—tenuity and porosity—are of slight importance compared with the chemical characteristics, a study of which latter includes examination into the nature and quantity of the gases that coal-dust may contain in the occluded state.

After having pointed out the relation which exists between the occlusion of gases and the origin of coal, the author describes the methods of investigation and results obtained in Germany by Prof. von Meyer, and also in Britain, where the combustible gas was found to consist, not only of fire-damp, but also of other and denser hydrocarbon gases. It is precisely, he remarks, on the larger or smaller quantity of these dense hydrocarbon gases that depends the degree of inflammability possessed by the coal-dust; and it is these occluded gases which, set free by a raising of the temperature, caused by a mine-shot for instance, combine with the oxygen of the air. A noteworthy circumstance is that their ignition-point is lower than that of fire-damp, and also that for bringing about an explosion they require a far larger volume of oxygen than does fire-damp.

This question is of the highest importance in countries like Belgium, where the coal-deposits are worked at a constantly increasing depth; and its study is the more easy, as all that is required is to apply established principles. J. W. P.

METHODS USED FOR DIMINISHING THE DANGER OF COAL-DUST IN THE GOVERNMENTAL COAL-MINES OF THE SAAR DISTRICT.

Die zur Bekämpfung des gefährlichen Kohlenstaubs auf den staatlichen Steinkohlengruben im Saarrevier getroffenen Einrichtungen, ihre Bewährung und ihre Kosten. *By* BERGINSPEKTOR ZORNER. *Glückauf*, 1895, *vol. xxxi., pages* 1207-1208.

The following are the chief methods of moistening coal-dust, used in this district:—

(1) The system of preventing dust before its formation, known as the Meissner system. This consists in drilling 1 to 3 holes, about 3 feet deep in the face, in the night-shift, plugging these holes, and forcing in water, which can then penetrate all portions of the solid coal. Generally, 8 hours suffice to soak the coal, so far that no dust is made during the process of getting the coal. The method is best suited for tender open coals, and is not suitable for hard coals, much fissured or jointed, or where either roof or floor are soft, and liable to swell.

(2) The dust may be damped down either continuously by spraying, or intermittently by water with hose, with or without a jet. The former method is more suitable for the travelling-roads where the air-current has considerable velocity, the latter for working-faces, though removable hoses that can be attached to hydrants, some 100 or 150 feet apart, are also used in the roadways. The former method consumes much water, but costs little for labour; whilst with the latter the opposite conditions prevail.

Instead of these methods, watering-carts, watering-pots, fire-engines, or force-pumps, may be used in particular cases.

(3) Wet zones, on wetted sections of the roads, should be maintained, so as to localize explosions as much as possible. Such sections should be 200 to 300 feet long, both in the main ways and in the return air-ways, so as to divide the various portions of a mine.

Cost of Plant.—The first cost of a system of pipes 39,400 feet (12,000 metres) long, at the Camphausen mine, was £1,500 in 1888, and has now risen to £8,200, with an extension of 19 miles (31 kilometres). The costs at the Maybach mine were similar,* and it may fairly be calculated that such an installation in a normal mine of area 1,400 metres (4,500 feet) by 1,000 metres (3,300), and working three seams, including connexions, taps, etc., would cost £2,500 to £3,000. The working costs have been reckoned at 2d. to 7d. per ton approximately. H. L.

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* *Trans. Fed. Inst.*, vol. ix., page 90.

ELECTROLYTIC GAS AS AN EXPLOSIVE.

Ueber Versuche mit Knallgaspatronen. *By* BERGASSESSOR HEISE. *Glückauf*, 1897, *vol. xxxiii., page* 869.

Dr. Wilhelm Ochse has patented a method of employing electrolytic gas, produced by the electrolysis of water, as a blasting agent. He uses small steel cylindrical shells 180 millimetres (7 inches) in length, 30 millimetres (1·2 inches) in diameter, and 2·5 millimetres (0·1 inch) in thickness; their volume amounts to 80 cubic centimetres (4·9 cubic inches), and they are calculated to withstand a pressure of 1,200 atmospheres. The cylinder is filled with 22.5 grammes (350 grains) of distilled water to which 2·5 grammes (38·5 grains) of chemically pure soda are added, so as to improve the electrical conductivity of the water. An iron plug is screwed in, through which pass two iron pins insulated by means of vulcanite. After the cylinder has thus been thoroughly closed, an electric current of 8 to 10 volts tension and 0·85 to 1·0 ampère strength is passed through the iron electrodes. According to the inventor, the evolution of oxygen and hydrogen depends only on the strength of the current, and is not affected by the pressure in the receiver. The water is slowly decomposed, the steel shell becoming slightly warm, owing to the compression of the gas. At the end of 40 hours, 20 grammes (308 grains) of water had been decomposed, the pressure inside the shell being equal to 450 atmospheres. In that condition, the shell was ready for use in the ordinary way like an ordinary cartridge of any explosive.

In sloping shot-holes, the shells must always be so charged that the stoppered end shall be uppermost. The shot is fired by sending a spark between the electrodes from a Nobel or Bornhardt electrical machine. If several shells are to be used in one shot-hole they must be connected in series and included in the current, because the explosion of a shell would not otherwise determine that of others in contact with it. The experiments tried with this method of shot-firing in stone indicated that the explosive force of a shell was about equal to that of 150 grammes (5 ounces) of any of the ordinary ammonium-nitrate explosives.

The inventor hoped that the extreme rapidity of the explosion of electrolytic gas would cause the extinction of all flame before the steel shell had time to burst, and that his method could therefore be used safely in gassy and dusty mines. Experiments, however, proved that this hope was ill-founded, and that these shells will fire explosive mixtures; the inventor had, therefore, not taken any steps towards the introduction of this new method of blasting. It is also doubtful whether it is adapted for practical working. H. L.

OCCURRENCE OF FIRE-DAMP WHILE SINKING IN THE RUHR COAL-FIELD, GERMANY.

Auftreten von Schlagwettern beim Abteufen des Schachtes Schürenberg des Steinkohlenbergwerks Ewald bei Herten. *By* BERGREFERENDAR VON VELSEN. *Glückauf*, 1896, *vol. xxxii., pages* 893-896.

Whereas, in the Ruhr coal-field, water has hitherto been regarded as the only difficulty of any consequence to be contended with in sinking shafts, another—that from fire-damp—showed itself while the Schürenberg shaft, 13 feet 3 inches (4·05 metres) in diameter, of the Ewald colliery was being put down. At the depth of 886 feet (270 metres) the marl was found to be much fissured; and, as it was feared that the clefts might reach down to the Coal-measures (the speedy occurrence of which was expected) and give out fire-damp, orders were given to try

for gas with the safety-lamp after every shot was fired and before each change of shift. This fear proved well founded, because on May 18th, 1896, fire-damp issued from a cleft in such quantities that it became necessary to interrupt the work.

When a depth of 98 feet (30 metres) had been reached, in order to provide the men at the bottom of the shaft with fresh air, an air-pipe 13 inches (34 centimetres) in diameter was put in and connected with a chimney on the surface, and lengthened as the work proceeded. When the fire-damp showed itself, a second air-pipe, 16 inches (40 centimetres) in diameter, was added, and connected with a Capell exhausting-fan 30 inches (75 centimetres) in diameter, which kept the bottom of the shaft so far free from gas that the work could be continued with special precautions—safety-lamps only being used, the dynamite-cartridges being fired by electricity, and the shots being tamped with water—while, after the holes were charged, the whole shaft-bottom was covered with water before firing. At the depth of 961 feet (293 metres) a crib was put in for the masonry-walling, which, on being carried up, closed the gas-yielding cleft. To prevent an accumulation of fire-damp behind the walling, a gas-pipe was built in; but the rocks again showed such large clefts, yielding fire-damp, that the sinking could proceed but slowly.

At the depth of 1,030 feet (314 metres), water under great pressure burst through two boreholes into the shaft, the flow ceasing after ½ hour; but the water was followed by fire-damp in such quantities, and under so great a pressure, that in an instant the whole shaft-bottom was filled with gas, so that the sinkers had to make their way up in the dark. In three hours the fire-damp stood 230 feet (70 metres) high in the shaft.

The above-named air-pipe was then replaced by two others, 16 inches and 20 inches (40 and 50 centimetres) in diameter, each connected with an exhausting-fan, which again freed the shaft-bottom from gas. As, however, fire-damp still showed itself in large quantities, portable incandescent electric lamps were used for lighting.

Further sinking of the shaft laid open a rather wide fissure, which gave out fire-damp; and, when the gas disengagement ceased, the remarkable circumstance occurred that the fissure sucked in water to such an extent that, in a week's time, the shaft-bottom became completely dry. On July 22nd, 1896, at a depth of 1,074 feet (327·4 metres), the Coal-measures were reached, containing the first seam of gas-coal, 9 inches (22 centimetres) thick, dipping 10 degrees; and from the fissured sandstone fire-damp issued with considerable force, accompanied by so loud a noise that not a word could be heard at the bottom of the shaft.

Six shots were to be fired the same evening; but only three could be charged, as the cartridges were blown out of the holes by the gas. The men were obliged to leave the shaft, because the gas increased so much that, about 10 p.m., it rose in the shaft to a height of 558 feet (170 metres); and although three fans were run at full speed, together exhausting 8,413 cubic feet (238·23 cubic metres) per minute, it was only possible to reduce the gas to a height of 105 feet (32 metres) above the pit-bottom. The two fans, which drew from the smaller air-pipes only, exhausted 4,088 cubic feet (115·77 cubic metres); while the other, drawing from the larger air-pipe, exhausted 4,335 cubic feet (122·75 cubic metres), or more than the other two fans together, the fans being of nearly equal power; and this circumstance shows what influence a reduction of the sectional area exerts on a fan's duty.

As it was found impossible to keep the shaft clear of gas by these small fans, a Winter ventilator, 9 feet 10 inches (3 metres) in diameter, guaranteed to exhaust 63,570 cubic feet (1,800 cubic metres) per minute, was erected, and put into communication with an air-tight box, 18 square feet (1·7 square metres) in sectional

area, led up to the surface. In two hours, it completely cleared the shaft of the gas, which had risen to the surface, so that sinking could proceed; and at the depth of 1,083 feet (330 metres) the fissure was closed by masonry, gas pipes being, at a further depth of 65 feet (20 metres), built behind the shaft-walling, and connected with the air-box. As considerable quantities of gas continued to issue from these pipes, they were united into one, led up to the surface; and the gas (containing 70 per cent. of fire-damp, with 1½ per cent. of carbon dioxide, the remainder being atmospheric air), was utilized for firing the steam-boilers. J. W. P.

OCCURRENCE OF INFLAMMABLE GAS IN ORE-MINES.

Förekomst af brännbar Gas i Malmgrufvor. *By* G. Nordenström. *Geologiska Föreningens i Stockholm Förhandlingar*, 1896, *vol. xviii.*, *page* 637.

A bore-hole was being bored by means of a diamond boring machine in one of the drifts of the Vieille Montagne Company's zinc-mines at Åmmeberg, when after boring 125 feet (38 metres) into granulite between two deposits of zinc blende, inflammable gas and water were given off in great quantity. The gas had the following composition:—

Light carburetted hydrogen, CH_4	51·0
Heavy ,, ,, C_2H_4	0·5
Carbon dioxide, CO_2	1·5
,, monoxide, CO	1·2
Hydrogen, H	1·0
Nitrogen, N	44·8

Under somewhat similar conditions, gas has been given off since 1893 from a bore-hole passing through alternate beds of hälleflinta and limestone in the Dannemora iron-ore mines. The bore-hole was plugged, but on withdrawing the plug water and inflammable gas escaped; the latter had this composition:—

Light carburetted hydrogen, CH_4	33·6
Nitrogen, N	66·4
	100·0

H. L.

VARIATIONS IN THE ISSUE OF FIRE-DAMP.

Du Grisou: ses Lois de périodicité. *By* A. Doneux. *Cosmos*, 1895, *vol. xxxi.*, *pages* 500 *and* 528; *vol. xxxii.*, *pages* 467 *and* 501; *and* 1896, *vol. xxxiii.*, *pages* 273 *and* 308.

The author, whose attention has long been concentrated on the periodicity of seismic disturbances, having been struck with the frequent occurrence of mining catastrophes traceable to no definitely ostensible cause—such as, for example, the explosion at Anderlues colliery on March 11th, 1892—was led to examine the question more minutely, with the result that he believes that by the application of Prof. Brück's ideas, a connexion may be traced between the issue of fire-damp and the laws of volcanic action.

From statistics of the mine explosions in Belgium between the years 1851 and 1879 arranged in Table I., it appears that, generally speaking, explosions occur most frequently at the end days of the magnetic week and at the period of the monthly change, for about three-fifths of the year, the remaining two-fifths not exhibiting this peculiarity, on account of other disturbing influences.

TABLE I.—FIRE-DAMP EXPLOSIONS (EX.), WITH KILLED (K.) AND INJURED (I.) IN BELGIUM FROM 1851 TO 1879, ARRANGED ACCORDING TO THE DAYS OF THE MAGNETIC WEEK.

Week		Days of the Weekly Fluctuation.																					
		1.			2.			3.			4.			5.			6.			7.		
		Ex.	K.	I.	Ex.	K.	I.	Ex.	K.	I.	Ex.	K.	I	Ex.	K.	I.	Ex.	K.	I.	Ex.	K.	I.
December 27 to January 2		1	0	6	1	5	2		—			—			—		1	2	7		—	
January 3 9		1	57	3	2	12	7	2	1	2		—		1	0	3		—			—	
,, 10-16			—		1	7	18	1	13	17		—			—			—		1	4	1
,, 17 23		1	8	18		—			—		1	0	1		—		3	27	7	2	0	1
,, 24-30			—		1	0	4		—			—			—			—			—	
January 31 to February 6		1	8	5	2	1	9		—			—		1	1	0		—		2	8	4
February 7-13	P	1	1	4		—		2	1	8	1	2	2		—			—			—	
,, 14-20		1	0	3	1	0	2	2	2	6		—			—			—			—	
,, 21-27	P	1	0	1		—			—			—		3	5	4		—			—	
,, 28 to March 6		2	27	11	3	9	8	3	1	8	2	5	14		—			—		2	66	6
March 7-13		2	1	1		—			—		1	1	2		—			—			—	
,, 14-20		1	0	3	1	2	5		—			—		1	0	4		—			—	
,, 21-27	P		—		1	5	16	1	2	3		—		1	3	0		—			—	
,, 28 to April 3		1	0	1	3	0	4	1	0	3	1	0	2		—		1	16	10		—	
April 4-10	P		—			—			—		1	1	0	1	0	3	1	1	2	1	6	0
,, 11-17		1	0	4	2	1	7	1	1	0		—		2	4	4		—		2	124	11
,, 18-24			—		1	1	1		—			—		2	2	2		—		1	0	6
,, 25 to May 1	P		—			—			—			—			—			—			—	
May 2-8			—			—		1	0	2		—			—		1	0	1		—	
,, 9-15		1	0	2		—			—			—			—			—		2	2	5
,, 16-22			—		1	1	6		—			—			—			—			—	
,, 23-29	P		—			—		1	2	0	1	2	0		—		2	11	0	1	1	0
,, 30 to June 5	P		—			—			—			—		1	1	4	1	2	1		—	
June 6-12			—		2	4	2	1	0	2		—		1	4	28		—			—	
,, 13-19			—			—			—			—			—		1	1	5	1	0	3
,, 20-26	P		—			—			—		2	2	4		—			—			—	
,, 27 to July 3	P		—		1	0	2		—			—			—		2	11	4		—	
July 4-10		1	1	0		—			—		1	13	4		—			—		3	4	3
,, 11-17	P		—			—			—			—		1	0	4		—			—	
,, 18 24	P		—			—			—		2	0	6	1	1	2		—			—	
,, 25-31			—		1	5	4	3	7	6		—		1	9	6		—		2	27	2
August 1 7			—		1	0	3		—			—			—			—		1	55	0
,, 8-14		4	1	7		—			—			—			—		1	1	0		—	
,, 15-21			—			—		1	0	2		—			—			—		1	1	0
,, 22-28		3	2	12	1	0	3		—		1	7	0		—			—			—	
,, 29 to September 4	P	1	1	1	1	20	9		—			—	4	2	9	9	1	3	0		—	
September 5-11			—			—			—			—			—			—			—	
,, 12-18	P	1	0	3		—			—		2	0	9	1	4	4		—		1	0	2
,, 19-25	P		—		2	2	0	1	9	4	1	2	1		—		1	1	1		—	
,, 27 to October 3		2	37	11	3	2	8		—			—			—		2	1	1		-	
October 4-10		1	3	13	1	0	11	1	1	0	1	0	1	1	0	11		—		1	4	0
,, 11-17			—			—			—			—			—			—		1	7	9
,, 18-24		2	2	0	2	2	7		—		1	1	1		—		1	34	3		—	
,, 25-31	P	1	7	0		-			—		1	2	5	1	2	0	2	3	4		—	
November 1-7			—			—			—			—			—			—			—	
,, 8-14	P		—		1	1	1	2	65	5		—		1	0	0	1	2	0		—	
,, 15-21	P	1	0	1		—			—		1	1	0	1	0	7		—			—	
,, 22-28			—		1	7	7		—			—			—			—		1	0	2
,, 29 to December 5			—		1	0	9		—			—		1	0	0		—			—	
December 6-12			—			—		1	1	1	1	0	6	1	0	2		—			—	
,, 13-19			—			—			—		1	112	10		—		1	2	3	2	14	5
,, 20-26			-			—			—			—			—			—		3	3	6

P indicates disturbing influences

If the figures given in the above-named statistics be grouped, the results shown in Table II. are obtained.

TABLE II.—EXPLOSIONS IN BELGIUM.

Days of the Magnetic Week.	1.	2.	3.	4.	5.	6.	7.
Number of explosions ...	*32*	*38*	25	23	26	23	*31*
Victims—Killed ...	*156*	87	106	151	45	118	*326*
,, Injured ...	*110*	*155*	69	68	97	49	66
,, Totals...	*266*	*242*	175	219	142	167	*392*
The averages per accident being—Killed ...	*4·8*	2·3	4·2	*6·5*	1 7	5·1	*10·5*
,, Injured ..	*3·4*	*4·1*	2·7	2·9	3·7	2·1	2·1
,, Totals	8·3	6·3	7·0	9·5	5·4	7·2	*12·6*

The effect of the monthly change on the escape of fire-damp is shown in Table III., wherein are detailed the number of explosions occurring on the day of this change and the seven days preceding and succeeding the same.

TABLE III.—EFFECT OF THE MONTHLY CHANGE ON FIRE-DAMP EXPLOSIONS IN BELGIUM FROM 1851 TO 1879.

First Day of the Monthly Change.	Number of Explosions in Belgium, 1851-1879.														
January 22	—	1	1	—	—	1	—	3	2	—	1	—	—	—	—
February 24	—	—	—	—	1	—	—	—	3	—	—	2	3	3	2
March 21 ...	1	1	—	—	1	—	—	—	1	1	—	1	—	—	1
April 16 ...	1	1	1	2	1	—	2	—	2	—	1	—	—	2	—
May 28 ...	—	—	—	—	1	1	—	2	1	—	—	—	—	1	1
June 21 ...	—	—	—	—	1	1	—	—	—	2	—	—	—	—	1
July 22 ...	1	—	—	—	—	—	2	1	—	—	—	—	1	3	1
August 8 ...	—	1	—	—	—	—	1	4	—	—	—	—	1	—	—
September23	1	—	1	—	2	1	1	—	1	—	2	3	—	—	—
October 10	—	1	1	1	1	1	—	1	—	—	—	—	—	—	1
November 9	—	—	—	—	—	—	—	1	2	—	1	1	—	1	—
December 16	1	1	—	—	—	—	—	1	—	1	2	2	—	—	—
Totals ...	5	6	4	3	8	5	6	13	12	4	7	9	5	10	7

First Day of the Monthly Change.	Number Killed.														
January 22	—	4	8	—	—	—	—	27	—	—	—	—	—	—	—
February 24	—	—	—	—	—	—	—	—	5	—	—	27	9	1	5
March 21 ...	—	2	—	—	—	—	—	—	5	2	—	3	—	—	—
April 16 ...	1	6	—	1	1	—	4	—	124	—	1	—	—	2	—
May 28 ...	—	—	—	—	2	2	—	11	1	—	—	—	—	1	2
June 21 ...	—	—	—	—	1	—	—	—	—	—	2	—	—	—	—
July 22 ...	—	—	—	—	—	—	—	1	—	—	—	5	7	—	9
August 8 ...	—	—	—	—	—	—	55	1	—	—	—	—	1	—	—
September23	4	—	—	—	2	9	2	—	1	—	37	2	—	—	—
October 10	—	3	—	1	—	—	—	4	—	—	—	—	—	—	7
November 9	—	—	—	—	—	—	—	1	65	—	—	2	—	—	—
December 16	—	—	—	—	—	—	—	112	—	2	14	—	—	—	—
Totals ...	5	15	8	2	6	11	61	157	201	4	54	39	17	4	23

The total number of explosions detailed in Table III. is 104, and if the individual totals be compared with the average of the 198 accidents recorded for the whole period under review, viz., 6·5, the two central days stand out prominently. Similar results are obtained from the statistics for France between 1814 and 1883. The number of killed recorded in Table III. (607), emphasizes the influence of the monthly change on the intensity of explosions, the average of the 3 central days being $139\frac{2}{3}$, whereas the average of the grand total only amounted to 32·52.

The annual change shown in Table IV. is somewhat similar in its effects, but in this case they are modified by the influence of the monthly changes.

Comparative indications are also given of the intensity of the explosions as manifested by the proportion of killed to wounded, the former being greatest on the day preceding the weekly fluctuation, and a reversal of the position occurring on the day following. In the case of the annual change, the killed predominate on the day succeeding the change, and the wounded on the next day.

TABLE IV.—INFLUENCE OF THE ANNUAL CHANGE ON THE FORCE OF FIRE-DAMP EXPLOSIONS IN BELGIUM FROM 1851 TO 1879.

First Day of Annual Change.	Number of Killed.														
January 1 ..	—	3	—	5	—	—	—	2	—	—	—	—	—	—	—
February 7	8	1	—	—	1	—	8	1	—	1	2	—	—	—	—
,, 20	—	—	—	2	—	—	—	—	—	—	—	—	5	—	—
March 7 ...	27	9	1	5	—	—	66	1	—	—	1	—	—	—	—
May 22 ...	2	—	1	—	—	—	—	—	—	—	2	2	—	11	1
July 18 ...	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
August 29...	2	—	—	7	—	—	—	1	20	—	—	9	3	—	—
December 21	—	—	112	—	2	14	—	—	—	—	—	—	3	—	5
Totals...	39	13	114	19	3	14	74	5	20	1	5	12	11	11	6

In considering the influence of lunar changes on the occurrence of accidents, Table V. shows the relation of explosions to the syzygies (the explosion represented by unity being placed in the position it occupies in relation to the centre of the syzygy) arranged according to the Metonic cycle (19 years). In the table, PL indicates full moon and NL new moon.

TABLE V.—INFLUENCE OF LUNAR CHANGE, AND RELATION OF EXPLOSIONS IN FRANCE TO THE CENTRE OF THE SYZYGY.

Cyc'e.		Explosions in France.														
1-1821, 1840,	PL ...	0	1	1	0	3	1	0	*6*	0	0	2	1	1	3	0
1859, 1878	NL ...	1	5	2	0	1	1	2	*0*	1	2	0	1	3	2	2
2-1822, 1841,	PL ...	1	1	0	3	1	0	3	*3*	2	1	0	1	3	3	2
1860, 1879	NL ...	1	2	1	2	1	0	2	*1*	2	2	2	1	0	2	1
3-1823, 1842,	PL ...	1	1	0	1	2	0	3	*2*	4	1	2	0	3	0	2
1861, 1880	NL ...	1	2	1	2	3	4	1	*1*	2	2	3	1	2	2	1
4-1824, 1843,	PL ...	0	1	0	5	2	2	2	*1*	1	3	2	2	1	0	0
1862, 1881	NL ...	0	0	3	0	1	1	4	*0*	1	1	1	1	1	2	1
5-1825, 1844,	PL ...	*2*	5	3	3	0	0	1	*2*	2	3	2	1	0	1	0
1863, 1882	NL ...	0	0	1	2	3	1	0	*0*	1	0	2	0	1	0	0
6-1826, 1845,	PL ...	1	2	2	1	0	0	3	*0*	4	2	1	1	0	1	1
1864, 1883	NL ...	1	0	2	1	0	1	0	*1*	1	0	0	3	2	2	2
7-1814, 1817, 1833-1836, 1852-1855,	PL	*6*	8	6	9	3	7	5	*8*	6	12	4	8	7	8	6
1871-1874, 1890, 1891	NL	4	10	6	7	9	8	1	*4*	2	4	4	7	8	3	5
8-1818-1820, 1837-1839, 1856-1858, 1875-1877	PL	2	11	2	6	4	2	6	*2*	3	3	4	7	5	3	3
	NL	8	2	4	8	6	10	3	*7*	8	9	4	5	6	8	2
		Explosions in France and Belgium.														
9-Jan. to April, 1863-1883 and Sept. to Dec., 1863-1878	PL	6	15	11	10	7	7	10	*12*	10	12	8	6	10	9	5
	NL	8	16	9	15	12	4	5	*5*	6	10	10	7	14	13	6
10-Aug. to Dec., 1879-1883	PL	0	0	2	2	2	3	4	*0*	3	1	4	1	1	2	0
	NL	2	0	2	1	0	2	1	*3*	1	2	5	0	0	3	0
Totals	PL	19	45	27	40	24	22	37	36	35	38	29	28	31	30	19
	NL	26	37	31	38	36	32	19	22	25	32	31	26	37	37	20

The symmetry and compensation noticeable in seismic convulsions is also apparent in Table V., maximum figures for PL being coincident with minima for NL in any one year. The effect of the new moon is less than that of the full moon, and the accidents are more evenly spread over the 15 days' period. Generally speaking, the figures increase on the sixth day before the syzygy and on the fifth and sixth days after, thus agreeing with the laws of volcanic activity.

The effect of the conjunction of a boreal lunestice with the annual change was well shown in the years 1876 and 1895, the Terrenoire colliery-explosion (186 deaths) occurring on February 4th, three days anterior to the annual change, and a number of storms, etc., at the same period of the former year.

The recurrence of seismic and kindred phenomena at intervals of 16 years is gone into by the author, who refers to a previous treatise on this subject, and Table VI. is drawn up with a view to demonstrating the influence of the same cycle on the issue of fire-damp.

TABLE VI.—EXPLOSIONS (N) AND VICTIMS (V) IN BELGIUM IN CYCLES OF 16 YEARS (1831-1878).

Years.		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	Totals.	Annual Averages.
1831 to 1846	N	6	3	4	6	9	3	4	14	13	18	13	11	9	7	10	10	140	8
	V	45	9	36	52	75	34	7	92	135	79	92	37	18	48	105	46	910	56
1847 to 1862	N	9	7	8	5	3	9	2	7	12	8	5	4	5	10	6	5	105	6
	V	87	41	43	90	23	130	12	39	64	79	19	37	20	46	45	79	854	53
1863 to 1878	N	8	6	5	9	3	4	7	7	5	9	9	9	6	5	5	10	107	6
	V	63	51	78	19	46	62	27	32	72	49	27	70	186	9	9	19	819	51

On grouping the elements of Table VI. into quadrennial periods, we obtain the results recorded in Table VII., showing that the largest number of explosions, etc., occur at the first and last years of the whole series of quadrennial periods taken together. Of the individual series, the third furnishes the greatest number (116), and this is worthy of note in that the first year of this series is the bi-quadrennial, a year of some importance in the cycle of volcanic phenomena; the average number of victims in this series is, however, smaller than in the others, showing a diminution in the intensity of the forces at work.

TABLE VII.—EXPLOSIONS AND VICTIMS IN BELGIUM IN QUADRENNIAL PERIODS.

A. Explosions.					B. Victims.					C. Number of Victims per 10 Average Explosions.				
1.	2.	3.	4.	Totals.	1.	2.	3.	4.	Totals.	1.	2.	3.	4.	Totals
23	16	17	20	76	195	101	152	161	609	85	63	90	80	318
15	16	13	28	72	144	226	46	163	579	96	141	35	58	330
30	35	27	24	116	271	207	138	144	760	90	59	51	60	260
20	22	21	25	88	224	103	159	144	630	112	47	76	58	293
88	89	78	97	352	834	637	495	612	2.578	383	310	252	256	1,201
Annual average 22					Annual average 161					Annual average 75				

Other tables grouping the results of the accidents into series containing over 5 killed, more than 10 injured and above 10 killed and injured combined, as well as statistics of accidents that occurred in French mines from 1815 to 1878, are also

given (Tables VIII. and IX.) with the idea of explaining more fully the relative intensity of the explosions in each year of the quadrennial period, and to show that the law of periodicity is generally applicable.

TABLE VIII.—NUMBER OF EXPLOSIONS IN BELGIUM ANNUALLY RESULTING IN AT LEAST:—

	5 Killed.				5 Injured.				10 Victims.			
1851-1854 ...	1	2	0	1	0	2	1	0	1	2	0	1
1855-1858 ...	2	1	0	2	1	5	1	1	2	3	0	1
1859-1862 ...	0	2	2	4	1	2	2	3	1	1	2	3
1863-1866 ..	1	1	2	0	1	4	0	0	2	1	1	0
1867-1870 ...	1	1	1	0	3	0	0	3	1	1	0	0
1871-1874 ...	2	4	1	3	1	1	0	5	2	1	0	2
1875-1878 ..	2	0	0	0	1	0	0	1	2	0	0	0
Totals ...	9	11	6	10	8	14	4	13	11	9	3	7
Victims corresponding to these numbers	264	235	89	112	101	103	31	98	367	277	93	150
Averages ...	29·3	21·3	14·8	11·2	12·6	7·3	7·5	7·5	33·1	31·7	31·0	21·4

TABLE IX.—EXPLOSIONS IN FRANCE DURING THE FOUR 16 YEARS' PERIODS FROM 1815 TO 1878.

Explosions					Victims.					Victims per 10 Mean Explosions.				
1.	2.	3.	4.	Totals.	1.	2.	3.	4.	Totals	1.	2.	3.	4.	Totals
30	27	38	45	140	98	87	157	103	445	33	33	41	25	132
34	50	51	58	193	262	145	178	187	772	77	30	35	33	175
41	53	53	74	221	258	171	127	173	729	63	33	25	23	144
42	36	50	32	160	110	99	211	80	500	25	28	43	25	121
147	166	192	209	714	728	502	673	543	2,446	198	124	144	106	572

The figures given in Table IX. (France) may be grouped into quadrennial periods as was done with the Belgian statistics, as shown in Table X. Thus

TABLE X.—EXPLOSIONS AND VICTIMS IN FRANCE IN QUADRENNIAL PERIODS.

Number of Killed.					Number of Injured.					The Number of Injured per 10 Killed.				
1.	2.	3.	4.	Totals.	1.	2.	3.	4.	Totals.	1.	2.	3.	4.	Totals
49	27	68	27	171	49	60	89	76	274	10	22	13	28	73
160	55	98	81	394	52	90	80	106	328	3	16	8	13	40
184	102	49	76	411	59	69	77	97	302	3	7	16	13	39
49	226	124	31	430	61	69	88	47	265	13	3	7	15	38
442	410	339	215	1,406	221	288	334	326	1,169	29	48	44	69	190

arranged, we see that in France the number of killed exceeds that of the injured, whilst in Belgium the former number decreased from the first to the fourth quadrennial term, the number of injured on the contrary rising; further, that the central pair of 4 years' terms show, when united, larger totals than the outer pair. The

number of men injured in France per 10 killed averages 11⅞; this average is exceeded in the second, third, fourth, sixth, eighth, eleventh, twelfth, thirteenth, and sixteenth years; in the first, fifth, seventh, ninth, tenth, fourteenth, and fifteenth years—which are the notable years in the volcanic cycle—the proportion of killed to wounded is highest.

From the table of mining accidents of all kinds, except from fire-damp, occurring in Belgium from 1855 to 1886, published in the *Annales des Travaux Publics*, the author draws the following conclusions:—

The ratio of killed to injured, per 10 accidents, decreases from the first to the fourth year of the general quadrennial, the minimum being, however, at the middle of the quadrennial period; and when the proportion of killed is high in any one year that of the injured is correspondingly low.

One exception is noted in Belgium, wherein the fourth quadrennial year gave a maximum number of victims, namely, in the period 1863-1878, owing to the terrible explosion of December 16th, 1875, resulting in 122 victims. Even in this case, the fourth period only shows 5 victims more than the third. Another instance is exemplified in France for the period 1847-1862, but here again the excess of the fourth over the third quadrennial period is but slight.

Table XI. shows clearly the regular course of the 16 years' cycle in France and Belgium.

TABLE XI.—INFLUENCE OF THE 16 YEARS' CYCLE IN BELGIUM AND FRANCE.

Sixteen Years' Cycle.		Belgium. Quadrennial Periods. 1.	2.	3.	4.	France. Quadrennial Periods. 1.	2.	3.	4.
1815-1830	N ..	—	—	—	—	13	27	23	6
	V ..	—	—	—	—	38	56	91	42
1831-1846	N ...	19	26	55	36	13	24	23	21
	V ...	142	208	353	217	72	65	102	46
1847-1862	N ...	29	21	29	26	31	46	84	71
	V ..	261	204	199	190	84	161	206	214
1863-1878	N ...	28	21	32	26	83	96	91	62
	V ...	211	165	218	223	251	490	320	196

NOTE.—N is the number of explosions, and V the number of victims.

The author lays it down as a principle fully established by the evidence, that the severity of the fire-damp explosions is usually greatest at the quadrennial years, decreasing from the first to the fourth year of each period, with, however, a tendency to increase again in the last year, so far as concerns the number of explosions. He considers that the attempted explanation of the cause of these explosions by the assumption that the gas is contained in "pockets" in the coal and becomes liberated in the course of working, is quite out of the question unless it be also assumed that the number of these pockets so exposed increases in certain years and on particular days in each year, which is hardly probable.

In examining the official figures of mining accidents in Belgium, from 1821 to 1879 (*Annales des Travaux Publics*, vol. xxxviii., page 120), in connexion with the influence of magnetic coincidences, it is found that the number of explosions occurring in the years of principal coincidences, together with the two years preceding and following, each amount to:—

A. Explosions: 108 ... 106 ... 107 ... 114 ... 125

Out of 16 such coincidences, two only (1838 and 1863) are irregular, in that the central number exceeds that on either side, and must be considered as "disturbed." Separated on this basis we have :—

2 disturbed coincidences :	9	...	9	...	22	...	19	... 23
14 regular coincidences :	99	..	97	...	85	...	95	... 102

As a rule, the number of accidents is lowest at the central year, but the number of victims is, on the contrary, abnormally high, thus agreeing with the effect of the quadrennial year. In the case of the secondary coincidences, however, although the number of accidents is greater than in the intermediate years, the number of victims does not increase in proportion, being almost constantly exceeded by the latter years : the most intense of the accidents being apparently produced within the period occupied by the quadrennial meridian, in traversing the 90 degrees preceding, and following the principal coincidence. This is independent of the influence of the fixed 16 years period, which causes exceptions to the rule, such as the accident at Monceaux-les-Mines, due to this influence and not to any conjunction of the quadrennial and secular periods.

The coincidence of March, 1892, confirms this principle in a striking manner. The occurrence of serious accidents, dated from about the middle of the previous year, increasing in quantity and severity up to March, 1892, and lasting another twelve months, concluding with the earthquakes in Greece, and various mining accidents during the first quarter of 1893. In 1894, the year of secondary coincidence, there were few accidents, but those occurring were of a serious nature, after which quiet was restored for a while. The next principal coincidence occurs at the end of April, 1896.

The results, obtained by an examination of French statistics, agree with the foregoing, only 4 coincidences being disturbed out of 19, and they occurred during the winter. Between 1829 and 1875 no disturbance occurred, the year of coincidence exhibiting throughout the highest number of victims from a small number of explosions, and the intermediate years the predominating number of slight accidents. C. S.

UTILIZATION OF FIRE-DAMP FOR LIGHTING PURPOSES.

La Récupération des Gaz grisouteux au Puits Saint-Guillaume, à Mährisch-Ostrau, Moravie. *By* H. SCHMERBER. *Le Génie Civil*, 1896, *vol. xxix., pages* 414-415.

A few years ago, in proving one of the coal-seams in the Moravian-Ostrau coal-field, a heading was driven in the seam for a length of about 350 feet (105 metres), in the course of which a constant and abundant disengagement of fire-damp occurred ; and the idea was then conceived of collecting this gas. Accordingly, the entrance of the heading was closed by a thick wall coated with cement, which imprisoned the gas ; and a pipe (2 inches in diameter) was arranged at the top of the wall, and led up to the surface by the Wilhelm shaft, terminating in a receiver, made from a boiler of 53 cubic feet (1·5 cubic metres) capacity, near the explosives-testing station. The receiver was provided with a water-gauge and scale which showed, at a glance, the exact extent to which it was filled or emptied.

Soon after the stopping in the heading was finished, a certain pressure of gas was noticed, which, however, did not exceed that corresponding with ⅓ inch (8 to 10 millimetres) of water, because, notwithstanding all the care taken to ensure tightness, there was constant and considerable escapes of gas, not only at the wall but also through the coal. It was afterwards found that the pressure was practically constant, notwithstanding the considerable quantities of gas used ; and this

pressure was only to a very slight extent influenced by variations of the barometer. The pressure of the gas in the pipe attained about 3·54 inches (90 millimetres) of water at the surface; and this difference of pressure, which might at first glance appear abnormal, is explained, first by the great difference of altitude, 656 feet (200 metres), between the bottom of the shaft and the surface; and secondly by the difference in the specific gravity of the two gases, that of the fire-damp in the pipe and that of the air in the shaft.

The gas might have been allowed to pass by its own pressure into the receiver, which, however, it was preferred to fill by aspiration with water, because in this manner gas might be introduced, not only of great pressure, but also of slight pressure or none at all.

In order to have a considerable quantity of gas constantly at command, two other receivers, like the first and of the same capacity, were put up and connected with it. Thanks to the precautions taken to prevent the entrance of air, the variations in the methane content did not exceed 7 or 8 per cent., the gases experimented with having a content varying from 85 to 93 per cent. of methane. Besides serving for experiments, the gas was used for lighting, being made to bubble through lime-water, on leaving which it had a tolerably high illuminating power. J. W. P.

COMPOSITION OF FIRE-DAMP.

Étude sur la Composition du Grisou. *By* TH. SCHLOESING, JUN. *Annales des Mines*, 1897, *vol. xi., pages* 5-37.

In a previous Abstract,* the results of several analyses of fire-damp, by Mr. Schloesing and the conclusions he arrived at concerning the combustible constituents thereof are given. In this paper, Mr. Schloesing reproduces these analyses and conclusions, and adds the result of investigations concerning the non-combustible constituents of fire-damp. For this purpose, samples of fire-damp were obtained, not by displacement of water, but by aspiration of gas under pressure from the solid coal. Nitrogen is always found in fire-damp, but in very variable proportion. In seven samples, the extreme proportions were 0·74 per cent. and 30 per cent. The author discusses the probable source of this nitrogen, and thinks it difficult to ascribe it to the nitrogenous constituents of the vegetable matter, from which the coal was formed, because, in slow decompositions reproduced in the laboratory, such great variations are not observed, nor, especially such large volumes of nitrogen liberated in proportion to the methane formed. It was, therefore, natural to think of the air as a possible source of the nitrogen in fire-damp, and the author suggests that the distinction between nitrogen proceeding from vegetable matter and nitrogen from the air might be founded on the presence of argon in the nitrogen. In preliminary trials, made with a mixture of several samples of nitrogen from fire-damp, 1·1 per cent. of argon was found. Samples of fire-damp, liberated under considerable pressure, were obtained, in one of which argon was found in practically the same proportion (1·18 per cent. corrected) as in atmospheric nitrogen (1·19 per cent.). In other samples, the proportion of argon to nitrogen varies from 1·09 to 3·28 per cent. The author thinks that if the nitrogen in these fire-damps was derived from the atmosphere, the air containing it must have been imprisoned in the coal about the time when the fire-damp was formed, and he refers to it as "fossil air." The possibility of atmospheric nitrogen being introduced, dissolved in water by percolation, is also suggested. The method of analysis is fully described.

* *Trans.*, vol. xi., page 611.

TABLE I.—RESULT OF EXPERIMENTS.

Source of the Samples of Fire-damp.	Pressure under which the Fire-damp was liberated in Water Column.	Volumes at 0° Cent. and 760 Millimetres.			Nitrogen with Argon in 100 Parts of Fire-damp.	Argon in 100 Parts of Fire-damp.	Argon in 00 Parts of Nitrogen and Argon.
		Fire-damp furnishing Nitrogen with Argon.	Nitrogen with Argon extracted.	Argon.	A.	B.	C.
	Centi-metres.	Litres.	Cubic Centi-metres.	Cubic Centi-metres.	Per Cent.	Per Cent.	Per Cent.
Anzin ...	400	3·5	634·0	20·78	18·1	0·594	3·28
Bessèges ...	4 to 5	4·9	186·7	3·04	3·8	0·064	1·63
Firminy ...	16	18·4	135·8	2·27	0·74	0·012	1·67
Liévin ...	70	5·5	437·1	9·71	8·0	0·166	2·22
Plat de Gier..	75	1·9	592·9	10·85	30·0	0·601	1 83
Ronchamp ...	8	9·1	255·4	2·79	2 8	0·031	1·09
Saint Etienne	600	15·5	497·5	5·81	3·2	0·037	1·17

An analysis of the gas liberated with such dangerous force and suddenness in the Rochebelle mines is as follows:—

Nitrogen and argon	1·14
Methane	0·73
Carbonic acid	98·13

Table II. indicates the presence of argon in the Rochebelle gas.

TABLE II.—ANALYSIS OF GASES.

Volume at 0° Cent. and 760 Millimetres.			Nitrogen with Argon in 100 Parts of Gas treated.	Argon in	
Rochebelle Gas treated.	Nitrogen with Argon extracted.	Argon.		100 Parts of Gas treated.	100 Parts of Nitrogen and Argon.
Litres.	Cubic Centimetres.	Cubic Centimetres.	Per Cent.	Per Cent.	Per Cent.
20·0	2228·9	4·29	1·14	0·021	1·87

The analyses of samples of coal for the detection of argon resulted in obtaining from 22 grammes of St. Etienne coal (undried) 243 cubic centimetres, or 0·304 gramme of nitrogen (1·38 per cent. by weight), and from 18·3 grammes of coal from the Plat de Gier, 196 cubic centimetres or 0·245 gramme, was obtained (1·34 per cent. by weight). Treated for argon, a residue of 0·05 cubic centimetre was obtained, or only one-fiftieth of the argon which would have been furnished by atmospheric nitrogen, and this residue might represent impurities from the reagents employed or small quantities of air in the apparatus. The coals examined contained at the most, if they contained any, $\frac{1}{100000}$ of an element comparable to argon.

The author further discusses the probable source of the nitrogen and argon in fire-damp, which, he thinks, cannot be the coal, but, without attaching great importance to the hypothesis, that they proceed from the atmosphere.

W. N. A.

ESTIMATION OF METHANE IN THE AIR OF MINES.

Ueber die Bestimmung des Methans in der Grubenluft. *By* ED. HANKUS. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1897, *vol. xlv., pages* 548-549.

The result of some 200 analyses of air taken from the same part of a coal-mine showed that, as a rule, the amount of methane present became larger as the barometer fell, and *vice versa*, the samples which contained 1 per cent. of methane when the barometric pressure was 29·547 to 29·725 inches (750·5 to 755 millimetres), being found to contain 1·2 per cent. when the pressure receded to 28·741 to 28·937 inches (730 to 735 millimetres). Some exceptions were noticed, but were attributed to fluctuations in the air-current.

From other experiments, it appears to be immaterial, so far as methane is concerned, whether the analysis of pit-air is performed as soon as the sample is taken or after several days' storage. On the other hand, the carbon dioxide becomes to some extent dissolved in any water present in the sampling vessel, and consequently the results for this gas may come out rather too low.

A more important influence, however, is exerted on the results by the presence of a greenish-brown sediment of organic matter in the storage-vessel. Such matter may be deposited from the water used to fill the vessel, or be contained in the pit-air; but whatever its source, the result of its presence is the gradual decomposition of the methane, and a corresponding increase in the carbon dioxide in the sample. In one instance, the initial quantities of 1 per cent. of methane and 0·2 per cent. of carbon dioxide were modified in 4 hours to 0·75 per cent. and 0·25 per cent. respectively, and the whole of the methane had disappeared in 20 hours. Similar results were obtained in other cases, the rate of decomposition varying in proportion to the amount of organic deposit present. To avoid such a *contretemps*, the author recommends that none but thoroughly-cleaned glass bottles should be employed for collecting and storing samples of such air and gas. C. S.

METHODS OF ASCERTAINING WHETHER FIRE-DAMP BE PURE METHANE.*

Original paper. *By* J. COQUILLION.

The gas disengaged from coal, designated by the name of fire-damp, may be either pure methane or a mixture of that gas with other gases. Its purity can be ascertained by two methods, that generally employed being the method by direct combustion. A few cubic centimetres (16 cubic centimetres = 1 cubic inch) are introduced into a eudiometer with sufficient air to ensure the completeness of the combustion; and an electric spark is made to pass through the mixture. The diminution of volume owing to the formation of the water-vapour, which is condensed, is observed; and then the carbonic acid is absorbed by potash, when a fresh diminution of volume will ensue, equal to half the former if the gas in question be pure methane.

The second method consists in decomposing the methane by means of water-vapour, in accordance with the formula:—

$$CH_4 + H_2O = CO + 6H$$
$$1 \text{ vol.} \quad = 1 \text{ vol.} + 3 \text{ vol.}$$

With this object, from 5 to 6 volumes of nitrogen are first introduced into a graduated test-tube, the sides of which have been carefully wetted. From 3 to 4 volumes of methane are then added, the addition of nitrogen not being indispensable; and then the U-burner is introduced into the tube, which rests upon mercury.

* *Trans. Fed. Inst.*, vol. xiii., page 60.

In order to form this U-burner, a piece of glass tube about 8 inches (2 decimetres) long and from 0·08 to 0·12 inch (2 to 3 millimetres) in diameter, receives a platinum or palladium wire, about 0·008 inch (0·2 millimetre) in diameter, projecting about 2 inches (from 4 to 5 centimetres) beyond each end. The glass tube is then bent into the form of a letter U, having one arm, that to be introduced into the graduated tube, rather shorter than the other, in order to facilitate the manipulation. The metal wire, on leaving this arm, forms a small spiral a few millimetres above the orifice of the tube, and then descends, parallel with this tube, for rather more than 1 inch (from 2 to 3 centimetres), being wound round the glass, while the other end of the metal wire is left free. To render the wire incandescent, one of the poles of a battery, or any other source of electricity, is plunged into the reservoir of mercury, while the other is inserted into the arm of the burner which remains outside the graduated tube.

After the metal wire is made incandescent, and when the volume of gas no longer increases, the burner is withdrawn. Sufficient time having been allowed for the gas to cool, it will be found, on observation, that 1 volume of methane has increased to 4 volumes, the increase being thus 3 volumes.

There would be great interest in ascertaining whether, in different collieries, the gas disengaged from the coal is more or less pure, and consequently more or less dangerous. J. W. P.

EXPERIMENTS WITH EXPLOSIVE MIXTURES.

Expériences sur les Mélanges explosifs. Original paper. By J. Coquillion.

Oxygen, when combining with hydrogen in a closed vessel, causes a detonation wellknown to chemists, who explain it in the following manner:—The steam which is formed, raised to a high temperature, suddenly drives the air before it, whence results a first shock; and this steam is condensed on the sides of the vessel, whereupon ensues the sudden entrance of air, which causes a second shock, following so closely on the former that the ear only perceives a single detonation.

With hydrocarbon gases (methane, ethylene, or acetylene) mingled with air or oxygen, the explanation is the same; but the products are different, as carbon dioxide and carbon monoxide are produced with a deposit of carbon if there be a deficiency of air or oxygen.

Detonations are easily caused, with suitable mixtures of air and explosive gases, by means of the electric spark, or by platinum or palladium wires raised to a white heat. With 1 part of fire-damp and about 6 parts of air, each electric spark causes a series of slight explosions; but, on increasing the quantity of air, only one detonation, stronger and more distinct, is obtained, while with 16 parts of air slight explosions are again obtained.

With platinum and palladium wires brought to a white heat, the limits of explosion are no longer the same; and the palladium wire causes much slighter detonations than platinum wire. While the electric spark determines a detonation almost immediately, the platinum and palladium wires only bring it about after a few tenths of a second from their being made incandescent.

Ethylene and acetylene produce stronger detonations than methane. A few experiments afford the impression that the gases found in different collieries possess explosive properties which vary with their origin; and there would be great interest in investigating the circumstances under which they are manifested, and this in connexion with coal-dust, which plays an important part in explosions, as has been shown by Mr. W. Galloway's experiments. J. W. P.

EXPLOSIBILITY OF FIRE-DAMP BY ELECTRIC CURRENTS.

Recherches sur l'Explosion des Mélanges grisouteux par les Courants électriques. By H. COURIOT *and* J. MEUNIER. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1898, *vol. cxxvi., pages* 750-753.

The authors, first of all, point out that there are three classes of electric phenomena which may have some action on explosive mixtures:—(1) Incandescence of a conducting wire, such as that of an electric lamp; (2) electric sparks, especially those due to breaking of the current; and (3) the voltaic arc formed between two carbons. They studied all these classes of phenomena, but they confine their present report to the results experimentally obtained in regard to the first two.

It was found impossible to ignite a current of fire-damp, containing 80 per cent. of methane, either in directing it against a metallic wire heated to incandescence by an electric current, or upon the current-breaking spark which arises on the fusion of the wire. The same experiment, repeated with ordinary illuminating-gas, determined immediate ignition. But, if a substance in flames be present, such as a lighted match, the fire-damp current ignited in the same way as the coal-gas.

In their further experiments, the authors no longer dealt with currents of gas, but led the explosive mixtures into a recipient over a pneumatic trough, and then, by means of an electric current, heated to redness a metallic wire (of varying lengths and diameters) placed in the midst of the gas. This wire was kept in place by two metallic conductors (various metals were tried), curved in such wise as to be easily brought into the glass jar. The ends alone of the conductors were left bare, so as to permit of the connecting wire being wound round them. Heating to redness soon resulted in the fusion of the wire, accompanied by a current-breaking spark. The following conclusions are arrived at:—

Electricity causes only one apparent phenomenon in the midst of a detonating mixture of fire-damp—that of explosion.

Metallic wires heated to redness by an electric current are powerless to determine detonation of even the most explosive mixtures. As long as the incandescent wire does not break, no explosion takes place. This explosion is due simply to the current-breaking spark; thus it may take place on the fusion of lead wires, which melt far below red heat. The sparks which are often produced between the incandescent wire and the metallic conductors do not cause explosion.

The combustion of the mixture is complete so long as the proportion of oxygen present is not less than 5·5 per cent. The most easily explosive mixtures are those which contain 9·5 per cent. of methane. The slightest change in the composition of the mixtures affects their liability to explode. L. L. B.

REGULATION OF THE EXPLOSIVES TO BE USED IN FIERY MINES AND IN DUSTY MINES WHERE DUSTS ARE INFLAMMABLE.

Explosifs de Sûreté; Calcul de la Température de Détonation. Annales des Mines, Recueil de Lois, Décrets, Arrêtes et autres Actes, 1896, *vol. v., pages* 466 *to* 468.

PARIS, *August 29th*, 1896.

TO THE PREFECT OF ———.

Acting in accordance with a circular of one of my predecessors of August 1st, 1890,* you have imposed on each fiery mine and each dusty mine whose dusts are inflammable in your department the use of safety-explosives, under conditions stipulated in the said circular. The temperature of detonation of these explosives

* *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp.* Translated by Messrs. W. J. Bird and M. Walton Brown, page 159.

must be below values determined according to the circumstances, and this temperature must be estimated by a calculation and in accordance with co-efficients that the said circular indicated for a number of substances contained in the model prefectoral decree.

Since that date further experiments have permitted the determination of the quantities of heat produced by decomposition and the specific heats with a much greater exactitude.

Moreover, it has appeared useful to give more extended co-efficients, so as to allow of the control of the temperatures of detonation of a greater number of explosives.

Consequently, in accordance with the indications which have been supplied to me by the Fire-damp Commission, I have decided that the two tables which are annexed to the model of the prefectoral decree attached to the circular of August 1st, 1896, should be replaced by the two attached tables prepared from those published in the *Mémorial des Poudres et Salpêtres* * and *Théorie des Explosifs*, by Mr. Emile Sarrau.

It will be unnecessary for you to make new decrees modifying those which you have already made, containing different values of the quantities of heat and of specific heat. It will be sufficient if you send copies of the present circular to all workers of mines concerned, who should be advised to consider it as modifying in an appropriate manner your former prefectoral decree.

You are desired to acknowledge to me the receipt of the present circular, which I have addressed in duplicate direct to the inspectors of mines.

The Minister of Public Works,

TURREL.

TABLE I.—QUANTITIES OF HEAT PRODUCED BY THE FORMATION OF SUBSTANCES DEDUCED FROM THEIR ELEMENTARY COMPOSITION, THE SUBSTANCES AND THEIR COMPOUNDS BEING TAKEN IN THEIR ACTUAL CONDITION AT a + 15 DEGREES.

Substances.	Formulæ.	Grammes.	Quantities of Heat. Calories.
Hydrogen compounds—			
Hydrochloric acid	HCl	= 36·5 ...	+ 22·0
Water (vapour)	H_2O	= 18·0 ...	+ 58·2
Water (liquid)	H_2O	= 18·0 ...	+ 69·0
Sulphuretted hydrogen ...	H_2S	= 31·0 ...	+ 4·8
Ammonium (gas)	NH_3	= 17·0 ...	+ 12·2
Oxygen and sulphur compounds—			
Nitrogen monoxide (gas) ...	N_2O	= 44·0 ...	− 20·6
,, ,, (liquid)	N_2O	= 44·0 ...	− 18·0
Nitrogen dioxide	NO	= 30·0 ...	− 21·6
Nitrogen tetroxide (liquid)...	NO_2	= 46·0 ...	+ 1·8
Nitric acid (liquid)	HNO_3	= 63·0 ...	+ 41·6
Carbon dioxide	CO_2	= 44·0 ...	+ 94·3
Carbon monoxide	CO	= 28·0 ...	+ 26·0
Sulphur dioxide	SO_2	= 64·0 ...	+ 69·2
Carbon disulphide (gas) ...	CS_2	= 76·0 ...	− 19·0
,, ,, (liquid)...	CS_2	= 76·0 ...	− 25·4
Nitrates—			
Ammonium nitrate	NH_4, NO_3	= 80·0 ...	+ 88·6
Potassium nitrate	KNO_3	= 101·0 ...	+ 119·0
Sodium nitrate	$NaNO_3$	= 85·0 ...	+ 110·6

* 1894, vol. vii., page 231 *et seq.*

Substances.	Formulæ.	Grammes.	Quantities of Heat. Calories.
Chlorates—			
Potassium chlorate	$KClO_3$	= 122·5 ...	+ 93·8
Sodium chlorate	$NaClO_3$	= 106·5 ...	+ 84·8
Carbonates—			
Potassium carbonate ...	K_2CO_3	= 138·0 ...	+ 278·8
Sodium carbonate	Na_2CO_3	= 106·0 ...	+ 274·8
Sulphates—			
Potassium sulphate	K_2SO_4	= 174·0 ...	+ 344·2
Sodium sulphate	Na_2SO_4	= 142·0 ...	+ 328·0
Sulphides—			
Potassium sulphide ...	K_2S	= 110·0 ...	+ 103·4
Sodium sulphide	Na_2S	= 78·0 ...	+ 89·2
Chlorides—			
Potassium chlorides... ...	KCl	= 74·5 ...	+ 105·7
Sodium chloride	NaCl	= 58·5 ...	+ 97·9
Hydrocarbon compounds—			
Acetylene	C_2H_2	= 26·0 ...	− 58·1
Ethylene	C_2H_4	= 28·0 ...	− 14·6
Ethane	C_2H_6	= 30·0 ...	+ 23 3
Methane (fire-damp) ...	CH_4	= 16·0 ...	+ 18·9
Benzol (gas)	C_6H_6	= 78·0 ...	− 11·3
,, (liquid)	C_6H_6	= 78·0 ...	− 4·1
Naphthalene (liquid) ...	$C_{10}H_8$	= 128·0 ...	− 27·4
,, (solid)	$C_{10}H_8$	= 128·0 ...	− 22·8
Phenols, alcohols, etc.—			
Phenol (liquid)	C_6H_6O	= 94·0 ...	+ 34·5
,, (solid)	C_6H_6O	= 94·0 ...	+ 36·8
Glycerine (liquid)	$C_3H_8O_3$	= 92·0 ...	+ 161·7
Mannite	$C_6H_{14}O_6$	= 182·0 ...	+ 320·0
Cellulose (cotton)	$C_{24}H_{40}O_{20}$	= 648·0 ...	+ 921·6
Ethers—			
Ethyl alcohol (gas)	C_2H_6O	= 46.0 ...	+ 51·4
Ether (gas)	$C_4H_{10}O$	= 74·0 ...	+ 62·8
Nitric ether	$C_2H_5NO_3$	= 91·0 ...	+ 48·7
Nitro-glycerine	$C_3H_53(NO_3)$	= 227·0 ...	+ 94·5
Nitro-mannite	$C_6H_86(NO_3)$	= 452·0 ...	+ 179·1
Gun-cotton—			
Endeca-nitric cellulose ...	$C_{24}H_{29}11(NO_3)O_9$	= 1143·0 ...	+ 631·0
Nono-nitric cellulose ...	$C_{24}H_{21}9(NO_3)O_{11}$	= 1053·0 ...	+ 681·0
Octo-nitric cellulose ...	$C_{24}H_{22}8(NO_3)O_{12}$	= 1008·0 ...	+ 706·0
Nitrogen compounds—			
Cyanogen (gas)	C_2N_2	= 52·0 ...	− 73·9
Fulminate of mercury ...	$HgC_2N_2O_2$	= 284·0 ...	− 63·5
Nitro-diazobenzol	$C_6H_5N_2NO_3$	= 167·0 ...	− 45·6
Picric acid	$C_6H_53(NO_2)O$	= 229·0 ...	+ 46·8
Picrate of ammonium ...	$C_6H_6O_7N_4$	= 246·0 ...	+ 80·1
Picrate of potassium ...	$C_6H_2KO_7N_3$	= 267·0 ...	+ 115·3
Nitro-benzol	$C_6H_5NO_2$	= 123·0 ...	+ 4·0
Dinitro-benzol	$C_6H_42(NO_2)$	= 168·0 ...	+ 13·0
Trinitro-benzol	$C_6H_53(NO_2)$	= 213·0 ...	+ 22·0

Substances.	Formulæ.	Grammes.	Quantities of Heat. Calories.
Nitrogen compounds—			
Nitro-naphthalene	$C_{10}H_7NO_2$	= 173·0 ...	— 14·7
Dinitro-naphthalene ...	$C_{10}H_6 2 (NO_2)$	= 218·0 ...	— 5·7
Trinitro-naphthalene ...	$C_{10}H_3 3 (NO_2)$	= 263·0 ...	+ 3·3
Potassium cyanide	KCN	= 65·0 ...	+ 29·4

TABLE II.—SPECIFIC HEATS (CALORIES) OF 1 GRAMME OF THE SOLID BODY.

Substances.	Specific Heats. Calories.
Barium carbonate	0·110
Potassium carbonate...	0·210
Sodium carbonate	0·270
Potassium sulphate	0·190
Sodium sulphate	0·229
Potassium sulphide	0·162
Sodium sulphide	0·228
Potassium chloride	0·173
Sodium chloride	0·213
Potassium cyanide	0·161
Silica	0·195
Wood charcoal	0·241

M. W. B.

DIMINISHING USE OF EXPLOSIVES IN BELGIAN COLLIERIES.

Emploi des Explosifs dans les Mines de houille de Belgique pendant l'Année 1895. *By* VICTOR WATTEYNE. *Annales des Mines de Belgique*, 1896, *vol. i., pages* 585-625.

By way of obtaining manageable figures for comparing the decrease in the use of explosives in Belgian collieries, the author has adopted the term "intensity of blasting" (*densité du minage*), which represents the quantities in kilogrammes of all kinds of explosives used in driving roads (ripping roof and floor) for every 1,000 tons of coal extracted multiplied by the mean thickness in metres of the seams worked. Belgian collieries are divided into four categories—non-fiery, slightly fiery (class i.), decidedly fiery (class ii.), and very fiery (class iii.)—each subject to different official regulations. Thus, the intensity of blasting in slightly fiery mines decreased from 29 in 1893 to 26 in 1894, but apparently rose to 27 in 1895; and in decidedly fiery mines it fell from 17 in 1893 to 15 in 1894, and 14 in 1895, while in very fiery mines these figures are 5, 4, and 3 respectively.

The new regulations as to explosives, which were promulgated by royal decree of December 13, 1895, mark an important era in the history of explosives consumption in collieries. Their main distinctive features are the interdiction (1) of the use of slow explosives (black powder, etc.,) for driving and enlarging roads (ripping roof and floor) in all mines decidedly fiery; (2) in the same mines, and for the same operations, of priming or firing methods that might project flame or ignited substances outside the shot-hole; (3) of all explosives without exception for the most dangerous case—that of driving and enlarging roads in fiery mines of all three classes; and (4) of blasting in dusty places. The regulations permit, however, the use of explosives for sinking shafts and driving cross-measure drifts.

The following are the considerations which led to the interdiction of explosives in the four different cases above-named :—

1.—The new Belgian regulations only forbid black-powder for ripping roof and floor because of its undoubted capability of igniting gassy or dusty mixtures; and preference is implicitly given to high explosives of such composition as emit, on detonating, but little flame capable of igniting fiery or gassy mixtures. Explosives may now be obtained which, if far from being absolutely safe, at any rate possess a considerable degree of security, especially if used judiciously, in moderate charges and well tamped.

2.—No improvements that may be introduced into the manufacture of explosives for suppressing the flame due to their deflagration or detonation will evidently be effective, if the method of priming or firing adopted be of itself capable of sending flame into the mine atmosphere. Other methods of firing, however, such as that by electricity, have already come into use, and are free from the above objections.

3.—Inasmuch as no explosive can yet, notwithstanding the improvements effected, be regarded as absolutely safe, blasting must always be dangerous in places where inflammable mixtures can exist or may form, whence the great restrictions introduced by the new regulations into the use of all explosives. These restrictions apply, for each class of mines, to certain points considered dangerous by their very position in the workings; and in this respect the Belgian regulations are more precise than most of those in other countries. Where, however, they are less explicit and, to a certain extent, less stringent than some of the latter, is in the conditions under which blasting is forbidden; and the "no fire-damp" of the regulations must be understood to mean such as may be detected by the lamp. The restrictions of 1895 may be suspended with previous permission, granted for a limited period but renewable.

4.—Now for the first time have measures been prescribed in Belgium against the danger of coal-dust; and their restriction to fiery mines is justified by the fact that, in that country, non-fiery mines are always but slightly, or not at all, dusty, while in scarcely any case is the dust they contain dangerous as regards inflammability. J. W. P.

FAVIERITE.

Les Explosifs de sûreté, leur Fabrication, leurs Propriétés et leurs Usages. By H. SCHMERBER. *Le Génie Civil*, 1896, *vol. xxx., pages* 100-104 *and* 115-117, *with drawings.*

If the chemical reaction between two substances be instantaneous and the products gaseous, formed at a very high temperature, and with great pressure, these substances constitute an explosive, which consists of two specific parts, viz., the supporter of combustible which determines combustion, and the combustible which supports it; the former supplies the latter with the oxygen necessary for its instantaneous combustion. Up to a few years ago, these two parts formed, in all the high explosives known, perfectly well-defined compounds; and the discovery of gun-cotton by Dr. Schönbein in 1845, that of nitro-glycerine by Prof. Sobrero in 1847, and especially its utilization as dynamite by Mr. Nobel in 1863, confirmed the idea that a true chemical combination was necessary to form a high explosive, this property, of being a well-defined compound, renders all these explosives very unstable, and therefore highly dangerous.

About 1873, Dr. Sprengel drew attention to the fact that safe and simple mixtures might be substituted for these dangerous combinations; and Major Favier undertook the long investigations which resulted in the introduction of the explosives bearing his name. Major Favier stated that in the detonation of nitrated

explosives there are two successive phases, the first which determines, by the action of an external energy, the dissociation of their elements, and the second, that during which these same elements, obeying their most intense affinities, disengage considerable quantities of heat, in consequence of which Major Favier arrived at the two following conclusions:—(1) Inasmuch as, in the detonation of nitrated derivatives, the original grouping of their atoms must be first destroyed, it is needless to incur the dangers which ensue from the fixation of the nitric elements on the hydrocarbons, while equally powerful explosives could be obtained by a simple juxtaposition of these same elements; and (2) it should be possible, by suitably increasing the force of the initial molecular shock necessary for determining the explosion of nitrated matters, to detonate substances which are stable under ordinary conditions. When these principles were once established, Major Favier fixed upon nitrate of ammonium as the substance determining the combustion, and for the combustible he gave preference to nitrated naphthalines, which substances were mixed so intimately that the dangers of true chemical combination were avoided, while the explosives were just as powerful as those formed by them.

Since the death of Major Favier, the manufacture of safety-explosives has been greatly improved; and the company which manufactures favierite in France supply six explosives, of which two are specially intended for dusty and fiery mines, their composition having been determined so that their detonation-temperature shall not attain 1,500° Cent. for the first and 1,900° Cent. for the second—temperatures adopted as limits by the French Fire-damp Commission for explosives that may be used in fiery mines for coal and rock respectively. The explosive for coal, which bears the name of *grisounite-couche*, is composed of 95½ parts of ammonium nitrate and 4½ parts of trinitro-naphthaline; and that for rock, designated *grisounite-roche*, of 91½ parts ammonium nitrate and 8½ parts dinitro-naphthaline, the respective temperatures of detonation (as calculated by Mr. Le Chatelier) being 1,445 and 1,875° Cent.

The author then describes the methods for producing the raw materials which enter into the composition of these safety-explosives, viz., nitrate of ammonium and nitro-naphthalines, and also their mixture (which in France is effected in the Government powder-mills), the putting up of the explosives into cartridges, their paraffining, packing, and the paraffining of the packets, which has more lately been adopted as an additional safeguard against damp.

Grisounite-couche, which detonates with greater difficulty than other explosives, on account of its slight content of matter supporting combustion, is charged loose into the cartridge-case, so as the more readily to respond to the action of the detonator; but the other explosives are compressed, with a view to increasing the density of the powder, and therefore diminishing the volume of the cartridge, while the core in contact with the fulminate is left pulverulent.

Some experimental trials made at Pavia on behalf of the Italian Minister for War showed that no explosion ensued through the impact of a falling weight, flattening a cartridge between sledge-hammer and anvil, the falling of a hundred cartridges from a height of 50 feet on to stone, or the passage over them of a train, while various tests have shown that favierite No. 1 exerts the same force as the strongest dynamite; and yet, notwithstanding its great stability, the explosive may be readily detonated with 15½ grains (1 gramme) of fulminate, though it is preferable to use double that quantity for grisounites. J. W. P.

UNDERGROUND DYNAMITE MAGAZINES.

(1). *Commission des Substances Explosives. Rapport sur les Expériences de Blanzy: Étude des Conditions d'Établissement des Dynamitières Souterraines. Annales des Mines*, 1897, *vol. xi., pages* 89-119, 6 *illustrations and* 1 *plate.*

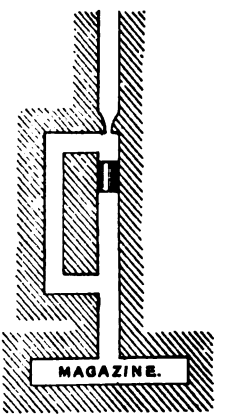
(2). *Commission du Grisou. Établissement des Dynamitières Souterraines: Rapport présenté a la Commission. By* — LEDOUX. *Ibid., pages* 517-543, *and* 6 *illustrations.*

Dynamite magazines, built, as usual, above ground, are open to a number of objections; thus they must be placed so far from inhabited buildings as to make it difficult or impossible to keep proper watch on them. The daily transport of explosives from the magazine to the mines presents some danger, especially in winter time, while in populous districts it is not easy to find a suitable site. Attempts have, therefore, been made to store explosives below ground, and in many countries it has been the practice thus to store 1½ to 2 cwts. of dynamite. In some cases it has been found desirable to store larger quantities, up to 2 tons, of dynamite underground, and the Fire-damp Commission was accordingly instructed to investigate this subject.

It was found, in the first place, that the dynamite should not be packed too closely, and that the minimum cubical contents of the magazine can be determined from the maximum weight that it is to contain, by the approximate formula, $V = 1{\cdot}6\ W$, where W is the weight of dynamite in pounds, and V is the minimum volume of the magazine in cubic feet. The boxes of dynamite should also be laid in a single row end to end, and not piled one above the other, so that the explosive force of the dynamite may not be localized. The depth below the surface or the distance that should separate the magazine from the nearest workings may be calculated from the formula—

$$R = 5{\cdot}8 \sqrt[3]{\frac{a\,C}{b}},$$

where R is the limit within which the shattering effect of the explosive will be felt, C is the weight in pounds of the explosive, a is a coefficient depending on the nature of the explosive, equal to 0·45 for black powder, 1·14 for dynamite No. 1 with 75 per cent. of nitroglycerine, and 1·60 for gelatine dynamite; whilst b is a coefficient depending upon the nature of the surrounding rock, being 1·25 for loose ground, 1·5 for ordinary ground, and 4 for rock. The limit as given by this formula should be doubled for the sake of safety.



The chief danger is due to the enormous pressure that the wave of the explosion would produce throughout the workings, and to the deleterious gaseous products of the explosion which would be driven into the workings of the mine. Preliminary experiments had shown that the only satisfactory method of obviating these dangers was by some means of automatically closing the communication between the magazine and the mine, as soon as an explosion occurs in the former. The method tried first, on a small scale, was the following:—The communication consists of a drift, circular in cross section; at a given point this drift is constricted to two-thirds of its diameter. On the magazine side of the constriction, and several feet away, is placed a stout plug that exactly fills the circular drift. Between the constriction and the plug there is a short drift at right angles to the main drift; from this

short drift another is driven, parallel for some little distance to the main drift, towards the magazine, and this parallel drift is again connected with the main drift by a short cross drift. There is thus a road always open between the magazine and the mine by means of the two cross drifts and the short parallel drift, which form a by-pass, whilst the straight main drift remains permanently obstructed by the plug. Should an explosion occur, the explosive wave will be propagated, and the products of explosion will tend to escape both along the straight drift and through the by-pass drift; in the former, the immediate effect will be to propel the plug against the constriction, which is arranged so as to form a seat for it, whilst so much more time will be occupied in traversing the by-pass drift with its two right-angled bends that the plug will have already been driven against its seat, and thus have effectually blocked all communication between the magazine and the mine. On a small scale this method answered well. Further experiments showed that a dynamite-magazine should be T-shaped in plan, the leg of the T forming the means of communication with the workings. It is found that in this way, from whatever point in the magazine the explosion may start, the pressures due to it are at a maximum at the ends of the head of the T which become nodal points, whilst its centre forms a ventral segment, at which the pressure due to the explosion is a minimum.

The system was tried at Blanzy; a drift was driven into the face of a quarry for a length of 160 feet, where the construction of the magazine proper commenced; a block of concrete was there built traversed (from inside outwards) by a circular drift 5 feet in diameter, and 6 feet 6 inches long; at this point the diameter was reduced to 3 feet 3 inches for a length of 3 feet 3 inches, whence it gradually widened out again to its original diameter. The face of the constricted portion, which was to form the seat of the plug, was strengthened by an iron framework. Towards the magazine, the circular drift in the concrete was prolonged some 10 feet in the country rock simply cemented smoothly on the inside; the plug was situated in this part of the drift. This plug was 5 feet in diameter and 5 feet long; for two-thirds of its length it consisted of circular sheets of stout pasteboard nailed together, whilst the remainder consisted of discs of soft poplar wood. The by-pass drift consisted of three sections, each 16 to 20 feet long and 5 feet 7 inches wide and high, timbered with ordinary sets. The opening furthest from the magazine, by which this by-pass drift enters the main drift, is fully open when the plug is in its normal position, but closed when it is blown against its seat. The distance from the back of the plug to its seat was 6 feet 2 inches. The magazine proper was about 25 feet from the plug; its full length was 33 feet, and its section 8 feet by 8 feet. Inside of it was arranged a charge of ½ ton of dynamite in boxes placed end to end along the floor of the magazine. When this charge was exploded a dull sound, accompanied by a slight tremor of the ground, was alone noticed; nothing was projected from the drift, and a tub standing at its mouth was not shifted. After a few seconds a small quantity of light yellowish smoke slowly escaped from the mouth of the drift. The timbering of the drift was intact, and the only part of the concrete block that was damaged was the portion that formed the seating of the plug.

In view of this successful experiment, the Commission is of opinion that with certain precautions an underground magazine of this type may be licensed for storing dynamite in amounts even exceeding ½ ton, provided that the conditions as to shapes and dimensions are strictly complied with. It is moreover recommended that it shall be forbidden to store black-powder underground, whether alone or with nitro-explosives. Detonators must not be stored in the same place as the

explosives. The explosives must be introduced and stored in closed boxes. These may only be opened and the cartridges handled in a separate chamber at least 65 feet from the magazine proper. Both these chambers must be illuminated by electric lamps or safety-lamps only. The magazine must be situated near the upcast shaft, and the drift leading to the magazine must be connected by cross drifts with the return airway, but must not open straight into this airway. Every drift shall have a blind end of about 7 feet in length, as this arrangement greatly lessens the force of an explosion. The drift that communicates with the magazine must be closed by a substantial grated door. The magazine must be ventilated by a pipe, the portion of which that passes by the seat for the plug, consisting of some waterproof material supported by a spiral of wire. Underground magazines that are not provided with a plug constructed as prescribed, shall not be licensed for more than 56 lbs. of dynamite.

Experiments have also been made with shallow underground magazines, and these tests are still in progress. So far, it would seem that favourable results have been obtained from a magazine placed at a sufficient depth below ground, the access to which is from a narrow trench, in the opposite face of which there is also a short drift to receive material projected from the drift leading to the magazine. The Commission seems to think that a magazine may be devised in some such way, a good deal safer than the existing type of above-ground magazines. H. L.

MAGAZINES FOR HIGH EXPLOSIVES.

Le Magasin Système Gathoye pour le Dépot d'Explosifs brisants. *By* JOSEPH LIBERT. *Annales des Mines de Belgique*, 1897, *vol. ii., pages* 105-109 *and* 1 *plate.*

A Belgian royal decree of October 29th, 1894, enjoins that every magazine containing dynamite, or explosives ignited with difficulty, if not situated underground, shall be visited every two hours during the day, and every hour during the night, by an armed watchman; but, while such guarding, unless continuous, is not absolutely efficacious, it involves great expense. Underground magazines may seriously compromise the safety of the workings, unless the site be absolutely unconnected with the working-places, while ministerial instructions of April 28th, 1896, forbid such magazines in the underground workings of fiery mines.

Mr. Léon Gathoye, manager of the Micheroux colliery at Soumagne, has solved the problem in another manner; and, not only has this magazine been erected at the above-named colliery, but its adoption is also under contemplation at other mines and quarries in the Liége district. It consists essentially of a domed cage, constructed of wrought-iron rods connected by flat bars, covered on the outside with 9 inches (24 centimetres) of brickwork, and lined inside with plaster, the ends of the rods, secured by flat bars, being surrounded by a cement foundation. The entrance is closed by three doors – the inner and outer of oak, and the former is also armoured on both faces with iron plates, while the middle door consists of a grating, the door-ways being well protected with iron, and each door being fitted with two locks. Six keys are required to give access to the magazine.

Article 271 of the regulations enjoins that the cases or packages of dynamite, etc., shall be contained in wooden cupboards with sides of at least $1\frac{3}{16}$ inch (3 centimetres) in thickness, closed by lock and key, and firmly fixed to the ground or walls, and this provision is more than fulfilled by Mr. Gathoye's magazine. The cupboards are of oak, lined with copper, and provided with special locks. Inasmuch as this magazine realizes a complete Faraday cage, inside which the electric potential is

absolutely *nil*, whatever be the atmospheric conditions outside, it is absolutely safe from lightning. In a magazine containing 6 cwts. (300 kilogrammes) of high explosives, the weight of iron required for the cage is about 1¼ tons (1,200 kilogrammes), which only adds about £20 (500 francs) to the cost of construction, while it fulfils every condition of security. J. W. P.

BEHAVIOUR OF EXPLOSIVES IN PRESENCE OF COAL-DUST AND FIRE-DAMP.

Versuche über Verhalten von Sprengstoffen gegenüber Kohlenstaub und Schlagwettern. *By* CARL PUSCH. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv., pages* 640-642.

Reviewing the researches on this subject published by Mr. Winkhaus,* the author points out that experiments in special galleries only partly approximate to the conditions obtaining in practical working, especially in those series where the cartridge was allowed to remain at the mouth of the cannon, and where stemming was omitted. In practice, accidents may occur in connexion with the bore-hole which will turn favourable into critical conditions, so that coal-dust and fire-damp penetrate the hole directly the shot is fired—a condition of which experiments do not afford the faintest indication. The results of these tests are therefore merely of relative merit, but capable of affording valuable indications—when combined with results obtained in practice—of the sphere within which explosives may be used with safety, and they are actually of great value as guides to the manufacturers of explosives, indicating the directions in which safety may be increased without loss of strength. C. S.

FURTHER EXPERIMENTS WITH EXPLOSIVES AT GELSENKIRCHEN.

Weitere Versuche betreffend das Verhalten von Sprengstoffen gegenüber Schlagwettern und Kohlenstaub auf der berggewerkschaftlichen Versuchsstrecke zu Braubauerschaft bei Gelsenkirchen. *By* BERGASSESSOR HEISE. *Glückauf*, 1897, *vol. xxxiii., pages* 517-523 *and* 544-549.

The experimental gallery at the No. 1 Consolidation pit was taken down and removed to another pit belonging to the same mine, where pit gas was available; its construction remained unchanged, except that it was sunk rather lower into the ground. The coal-dust used in the experiments was finely ground coal containing 28 per cent. of volatile matter, whilst in previous experiments fine coal from the screens had been used. A number of experiments were tried with explosives in suspended coal-dust without gas, suspended coal-dust with 2½ per cent. of gas, and suspended coal-dust with 6½ per cent. of gas, 9 per cent. being used in some special experiments with kohlen-karbonit. The composition of the explosives used and the results obtained in the experiments are recorded with much detail. It was found that considerably more ignitions were obtained in this new gallery than had been the case in the old one; the cause of this greater sensitiveness was suggested to be the greater depth of the new gallery preventing the products of the shot escaping as freely as was previously the case, or else that the finely ground coal-dust was more readily ignited than was the dust used in the earlier trials. An addition of even 2½ per cent. of pit gas was found to notably increase the risk of explosion, and it was noticed that in the presence of even this small proportion of gas the flame of a blown-out dynamite shot was markedly lengthened.

No. 1 roburite gave anomalous and unsatisfactory results, and was found to be far less safe than formerly, though its composition was unchanged; exhaustive

* *Trans. Fed. Inst.*, vol. ix., page 250; and vol. x., pages 161 and 337.

experiments seem to indicate that the purity or otherwise of the chemicals employed in its manufacture had little to do with this irregularity, but that the mode of manufacture had a marked influence; and more especially, that intimate mixture and fine grinding produced a much safer explosive than did the opposite conditions. The author points out that to know the chemical composition and the thence calculated temperature of detonation of an ammonium-nitrate explosive is not sufficient, and that the method of manufacture must also be taken into account.

Finally, tests of some recently introduced safety explosives are also recorded.

H. L.

ELECTRIC SHOT-FIRING IN COLLIERIES.

Elektrische Zündung der Schüsse in Kohlenbergwerken. ANON. *Glückauf*, 1896, *vol. xxxii., pages* 985-988, *and* 1 *plate and figures.*

Great progress has been made in safety blasting-powders and in the safe firing of shots, electricity being applied to the latter. Electrical machines that produce a current of very low tension, so-called incandescent igniters, would seem to be best suited for coal-mining, as there is no chance of sparks being produced, but it must not be forgotten that these machines are not constant in their action and need continual repairs, whilst the detonators to be used with them are far too dear to be used in practice.

The first forms of high-tension machines or so-called spark igniters were a source of danger owing to the long high-tension sparks produced in case of a short circuit. This system had only become suitable for mining purposes since it had been found possible to construct machines of such low tension that the spark was no longer visible, and was incapable of igniting fire-damp, and since detonators had been produced sufficiently sensitive to be fired by these light electric currents.

Such machines have been proposed in France and England, but the machines used in these countries work at too high a tension, and were much too unhandy. A little machine had lately been put on the market by the Roburite factory at Witten that seemed likely to prove of permanent value in coal-mining. It consisted of a box 4·5 inches by 4·33 inches by 3·5 inches, and comprised a Siemens armature rotated by gearing between the poles of a pair of horseshoe magnets. The weight of the entire machine was about 4 lbs. The alternating current generated by this machine is of 6 volts, 0·5 ampère and 800 ohms, and is so feeble that it can scarcely be felt. The mixture with which the detonators are charged is so sensitive that a quarter turn of the handle is generally sufficient to fire it. It is only intended to fire one shot at a time. The machine is so arranged that the shot can only be fired if the contact button is pressed down whilst the handle is being turned.

These machines have been experimented on for some time at the Bonifacius mine near Krey; 890 shots were fired in coal and 250 in stone with not quite 1 per cent. of miss-fires.

The costs of the detonators per shot were:—In coal, 0·14 mark (1·6d.); in stone, 0·12 mark (1·4d.). Shots fired with safety-fuzes and Roth safety-igniters cost respectively 0·15 mark (1·8d.) and 0·13 mark (1·5d.). A small amount should be added to the former for amortisation and wear of the machines and leading wires. The machines cost 30s. The miners complained of loss of time, owing to the machine only firing shots singly, an objection that may be overcome by using larger machines. The manufacturers are now engaged on a time-igniter, to enable several shots to be fired one after the other by a simultaneous electric discharge through them.

H. L.

ELECTRICAL SHOT-FIRING, WITH REFERENCE TO ITS EMPLOYMENT IN THE PRESENCE OF FIRE-DAMP IN COLLIERIES.

Elektrische Zündung mit Rücksicht auf ihre Verwendung in Schlagwetter führenden Gruben. *By* JOHANN VON LAUER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv.*, *pages* 599-602, 609-614, 627-631, 637-640, 650-654, *and* 669-673, *and* 1 *plate.*

Five forms of electric shot-firing may be distinguished:—(1) Frictional; (2) galvanic; (3) inductive; (4) magneto-electric; and (5) dynamo-electric.

1.—These machines consist of either discs or cylinders of glass or vulcanite, working against rubbers, the electricity generated being collected in Leyden jars or condensers. The conductors are best made of soft copper-wire, insulated by means of guttapercha, or by attachment to insulators. The igniters consists of a quantity of easily inflammable material, in which the two ends of the conductor, 0·04 to 0·20 millimetres apart, are embedded.

The advantages of the frictional electric system are, that a large number of shots (250 to 300) can be fired simultaneously with an easily portable machine, and even although the igniters are of unequal resistance. The machine, being hermetically sealed, needs no especially careful handling, and requires no repairs of any importance. The conductor may be of any kind of wire, and the igniters can easily be made very substantial.

This system has hardly any disadvantages, except, perhaps, that the current has to be generated immediately before the shot is to be fired; hence this method can be used in every kind of shot-firing.

2.—Any form of battery may be used, bichromate and Leclanché elements being the most suitable; secondary batteries (accumulators) might also be used. The current being a feeble one, the leads must consist of good copper wires of considerable section, well insulated. The igniter consists of a fine platinum (or german silver) wire connecting two insulated wires and embedded in an easily fired mass of guncotton, meal-powder, or a mixture of antimony sulphide and potassium chlorate. Care must be taken to select igniters of about the same resistance, otherwise those with the highest resistance would explode first and destroy the connexion, unless the shots were arranged in parallel circuits. It is scarcely possible to produce a battery that shall not be unwieldy to fire more than 10 or 12 shots simultaneously. Although by this system it is possible to test the circuit by means of currents too feeble to cause ignition, and it possesses the advantage of being always ready for immediate firing, it is too cumbersome, and has too many objections to have been adopted for technical purposes.

3.—The electric current is generated by a Ruhmkorff coil, combined with a battery; the method is in general somewhat like 1, and possesses most of its advantages, but suffers from the objection of having to employ galvanic batteries.

4.—Magneto-electric machines are somewhat similar in the character of the current, etc., to frictional machines and igniters of the same type, but are much more sensitive, and are employed because the current is much feebler. These machines are not affected by atmospheric influences, and are reliable, but have too little power in proportion to their weight, and need highly sensitive igniters to fire several shots at one time.

5.—This method differs from the last-named in that permanent magnets are not employed, but electro-magnets whose magnetism is induced by the action of the armature. The currents are of low tension, and need highly sensitive igniters and very perfect conductors. The efficiency of these machines is low, and the system is considerably inferior to those using frictional and induced electric currents.

The author considers that the use of accumulators is to be preferred to every other method, using a current of low tension but considerable intensity, capable of firing two or three shots at a time, and using an igniter with platinum wire. He looks upon this as the safest method in the presence of fire-damp. H. L.

BOHEMIAN FELSPAR INDUSTRY.

Böhmens Feldspathindustrie. *By* Dr. FRIEDRICH KATZER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, *vol. xliv.*, *pages* 647-650.

Established about 50 years ago, the industry of felspar-quarrying in Bohemia has had a chequered existence, owing to the irregular occurrence of the mineral in isolated masses of pegmatite—which, being quickly exhausted when the demand was brisk, necessitated constant prospecting for fresh sources—and the fluctuations in the trade.

The earliest quarries were situated in the vicinity of Horaždiowitz, and yielded felspar and quartz, but their exhaustion led to the development of the more plentiful pegmatite and granitic deposits in the gneiss district further east. At the village of Skal, near Ražitz, a very pure grey microcline, almost free from soda and lime, was worked for a long time, and the district contains numerous outcrops of pegmatite still undeveloped. Another famous quarry was that of "U Obrázku," belonging to the municipality of Pisek, which yielded a grey felspar, in addition to a large number of rare minerals prized by collectors.

This quarry has been abandoned for some time owing to the failing demand for the product. Another deposit, in the Paseka district, yielded a large quantity of felspar and quartz in 1894, but was also abandoned for the above reason. A yellow microcline is found near the Jamny road, north-east of Pisek and close to the Moldau, the pegmatite-deposit here being of considerable extent. Again, in the neighbourhood of Kloub, near Protivin, a large deposit of pegmatite, in biotite, yields an exceedingly pure felspar, entirely free from lime, and containing only a minute proportion of soda. This product is in good demand, on account of its quality and fusibility. Near Wällischbirken, a milk-blue to grey felspar, of very good quality, is won from a communal quarry, but would not meet with much sale were the price not very low—a condition rendered possible by the extraordinarily low rates of wages current in the district. C. S.

FORMATION OF HYDROGEN CARBIDES BY THE ACTION OF WATER.

Sur la Formation des Carbures d'Hydrogène gazeux et liquides par l'Action de l'Eau sur les Carbures métalliques: Classification des Carbures. *By* HENRI MOISSAN. *Comptes Rendus de l'Académie des Sciences*, 1896, *vol. cxxii.*, *page* 1462.

The reaction which appeared to the author the most remarkable in the experiments connected with this subject is the easy production of hydrogen carbides, gaseous, liquid, or solid, by the action of cold water on certain metallic carbides; and he considered that these studies might possess interest for geologists. The disengagements of methane, more or less pure, noticed in some measures, and which have lasted for centuries, might originate in the action of water on carbide of aluminium; and a reaction of the same nature might explain the formation of liquid carbides. Starting with 9 lbs. (4 kilogrammes) of uranium carbide, the author obtained, in a single experiment, 3½ ounces (more than 100 grammes) of liquid carbides; and this mixture is chiefly composed of ethylenic carbides, with a small quantity of acety-

lenic and saturated carbides, which were generated, in the presence of a large proportion of methane and hydrogen, at the ordinary pressure and temperature, inducing the belief that, with a high temperature during the decomposition, saturated carbides similar to rock-oils might be produced.

The existence of these new metallic carbides, that can be destroyed by water, may modify the opinions hitherto entertained as to the formation of petroleum; and there exist, in all probability, rock-oils of different origins. While at Autun, the bituminous shales appear to have been produced by the decomposition of organic matter, asphalt impregnates all the fissures of the lacustrine limestone in the Limagne, this asphalt being in direct connexion with the basaltic tufa, and consequently in evident relation with the volcanic eruptions of the district. A recent bore-hole at Riom, which attained the depth of 3,936 feet (1,200 metres), brought to the surface a small quantity of petroleum; and the formation of this liquid carbide may in that case be attributed to the action of water on metallic carbides.

It is probable that, during the first geological periods of the earth's history, almost all the carbon occurred in the form of metallic carbides; and, when water intervened in the reactions, the metallic carbides yielded hydrogen carbides, and the latter carbonic acid by oxidation. An example of this reaction is, perhaps, afforded in the neighbourhood of Saint Nectaire, where the granites, which form the edge of the Tertiary basin, allow a large quantity of carbonic acid gas to escape continuously. Certain volcanic phenomena may also be attributed to the action of water on easily-decomposed metallic carbides, for geologists know full well that the last manifestation of a volcanic centre consists in very varied carburetted emanations, from asphalt and petroleum to carbon dioxide, which is the last term of all oxidation. J. W. P.

USE OF OXYGEN IN RESCUE OPERATIONS.

Verwendung des Sauerstoffes für Rettungszwecke. *By* BERGINGENIEUR ROSSNER. *Berg- und Huettenmœnnische Zeitung*, 1897, *vol. lvi.*, *pages* 193-196.

In the Elkan apparatus, an indiarubber bag is used for the transport of the oxygen from the steel storage-cylinders to the place of the accident, the gas being supplied to the sufferer by means of an indiarubber pipe, with a vulcanite-nozzle for insertion into the nostrils. When inserted in the mouth, the patient, in recovering, presses his teeth together, and might injure them on the nozzle.

At the Archduke Frederick's works, in Austrian Silesia, oxygen is kept stored in cylinders, and has already been the means of preserving workmen's lives. In March, 1896, an attendant was stupefied and burnt by blast-furnace gases, and became unconscious. Oxygen was introduced through the nose into the lungs of the sufferer, who speedily recovered consciousness. In December, 1896, four men were overcome by the fumes of an anti-corrosive paint in the inside of a boiler. A boilerminder and another workman who followed them into the boiler were also overcome, so that six men were lying unconscious in the boiler. After the lapse of several hours, the engineer emptied two cylinders containing in all about 70 cubic feet of oxygen into the boiler, whereupon the breathing of the victims was heard, and soon afterwards four of the workmen crawled out unaided. The other two workmen lay between the side of the boiler and the furnace-tube, and 70 cubic feet of oxygen was blown upon them through a hose, with the result that in a short time they, too, were able to make their way out unaided. In March, 1897, oxygen restored a family who had been poisoned by carbon monoxide.

In rescue work, a single individual carrying a supply of oxygen in any portable form may afford assistance by applying oxygen to the nostrils of injured persons. It is, however, desirable for rescuers to work, not singly, but in parties of three or four, so as to afford mutual assistance to each other. Two men can thus carry an injured workman for a short distance; in other cases, some form of litter should be adopted. Rescuers, if supplied with oxygen from a portable apparatus, by working in relays, may assist largely in the erection of stoppings, the erection or repair of ventilating-doors, brattices, etc. It would also be desirable that each workman should be provided with a reserve apparatus for use on the return journey, should he happen to penetrate too far into the workings and have an insufficient supply of oxygen left for his return. M. W. B.

HARKORT GOLD-MINES IN TRANSYLVANIA, HUNGARY.

Harkort'sche Bergwerke in Siebenbürgen. *By* AD. SCHÖNEMANN. *Zeitschrift für praktische Geologie*, 1896, *page* 453.

These mines have been developed on a large scale and supply 125 heads of stamps at Brad and 66 at Kristor, with a total quantity of 5,500 tons of auriferous quartz per month. This amount of quartz yields on the average 1,285 ounces of gold, the coarse gold that is first picked out and treated separately amounting to between 645 and 965 ounces per month. Concentrates and residues at the year's end give about as much also, so that the annual output would be about 25,720 ounces, worth about £80,000. In 1895-96, the production was 21,235 ounces, the cost of production being about £40,000, there being some 980 men employed. The deposits are fissure-veins traversing the eruptive rocks and tufas of the Erzgebirge of Transylvania, are more or less regular, and maintain their course both in dip and strike for considerable distances. Though originally worked by the Romans, new discoveries are nevertheless being made in these deposits.

H. L.

HISTORY OF GOLD-MINING IN THE ZILLER-THAL, AUSTRIA.

Zur Geschichte des Zeller Goldbergbaues. *By* MAX REICHSRITTER VON WOLFSKRON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, *vol. xliii.*, *pages* 349-353, 368-373, 383-387, 399-402, 411-414, 426-429, 441-444, *and* 455-457.

The gold-mining industry in the Salzburg district dates from the year 1427, when the Duke of Tyrol, the then Emperor of Germany, and the Archbishop of Salzburg agreed to work a mine in the district for gold and silver, but the project remained in abeyance for 200 years, when mining operations seem to have been vigorously started in the Ziller-Thal. Although the value of gold was at that time much higher than at present, other minerals were at first sought for, but in 1630 fine alluvial gold was discovered, and soon after rich gold ore. The find was of sufficient importance to bring the Archduke Leopold of Austria in person to inspect it. As the gold was on Salzburg territory, half, according to an old compact, was to belong to the Archduke, and the other half to the Archbishop of Salzburg. Taking advantage of a verbal quibble, the latter refused to admit the Archduke to a share, and caused the workings to be forcibly interrupted, and the gold-plant destroyed. War would have ensued had not the Emperor and the States of the Tyrol prevented it. In the neighbouring works, however, the mining industry was continued. The ore appears to have been dug from the mines, crushed, soaked, and washed,

of course, by hand and in primitive fashion. The percentage of gold was considered high, varying from 1½ to 2¼ ounces per ton. About the year 1633, 73 persons were employed in quarrying, crushing and washing the ore, at an average weekly wage of about 2s. 6d. The vein of ore was rich in gold, and well repaid the cost of working, but as the mines were pushed deeper, it was found increasingly difficult to amalgamate the gold, because it contained much arsenic. Many of the workings were discontinued on that account, as the century advanced, and for 20 or 30 years they were practically abandoned. An attempt was then made to melt down the heaps of waste ore, but the proportion of arsenic was so great that it poisoned the workers. Another drawback was that too much water was used in dressing the ore.

The long contest between Salzburg and Tyrol at length ended in an agreement to work the mines in common, the miners being taken from both districts, and the managers alternately from one or the other. Gold in 1650 had a purchasing power 2½ times more than at present, and the workmen's wages were higher relatively, considering the wretched quality of the work done. In 1681, there were 411 workmen employed, and blasting had been resorted to. This resulted in a find of extremely rich ore containing 107 ounces to the ton, and in 1686 the rich ore lately so profitably worked by the Bavarian government was opened up. By the end of the century, these rich seams had given out, and the Zeller mines were for the time partly abandoned, as with the rise in the price of commodities and provisions they no longer paid for working, although some of them were free from water. Even for that period they were not worked economically, and in 1713 a commission was appointed to examine into the expenditure. As far as possible, it was decided to do the work by contract, and to raise less barren rock to the surface. The props of the mine were strengthened, the slick more carefully washed that less gold might escape, and great efforts were made to extract gold, even by alchemy, from the waste slick and tailings. In 1746, a primitive form of the Salzburg bump-table for dressing the ore was introduced, and the initial difficulties were successfully overcome. Various empirical methods were suggested for liberating a larger quantity of gold. One quack proposed to extract it with a costly preparation of spirits of salt, possibly connected with muriatic acid which is now so much used in the process, but he did not even gain a hearing.

The method of obtaining gold was complicated. It was first crushed, washed, amalgamated and smelted; the gold slick was then conveyed to the smelting-works, washed, mixed with lead, refined, and finally separated by quartation. All these processes were not only very costly, but much gold was lost. Nor was the Salzburg table found to give satisfactory results, because the slick was so fine that the gold-dust escaped. In 1753, it was determined to set up several buddles, worked apparently by water-power, and a new kind of bore was introduced. Documents are still extant, showing the output of gold from 1660 to 1756. During this period, the average quantity of gold sent to the mint to be refined each year was about 5,000 lbs. and the output of ore about 1,000,000 tons. The proportion of gold varied from 0·047 to 0·145 ounces (1·3 grammes to 4 grammes) per ton, the Zeller ore being always high-graded. The fineness of the gold bullion during the first half of the eighteenth century was 950. The deeper the works were carried the richer was the gold-bearing quartz, but the cost of working rose in proportion. Allowing for the higher purchasing power of money, which was about double its present value 100 years ago, it cost 15s. 6d. per ton to work the ore, and this figure steadily rose, especially in the deeper mines, from which much water had to be pumped. The price may be taken at double what

it would be at present, owing to bad work and waste, particularly of blasting-powder. In some shafts, the output was only 2·8 cubic feet per shift per man. The concentrated slick was so rich, containing 26·4 ounces of gold per ton, that thefts by the workmen were common. The introduction of buddles diminished the number of men employed, but even with this mechanical help it is surprising that the works should have been carried on so long under such disadvantages. In 1786, the Borus system of amalgamation was applied to extract the gold, and towards the end of the century great efforts were made to remedy the defects in working the mines. It was proposed to dress the quartz, the slate, and the broken rock separately, and to concentrate the tailings, which had hitherto been sold as waste. The wages of the workmen were also raised, to prevent dishonesty.

At the beginning of this century, the see of the Archbishop of Salzburg was abolished, and the country passed to the Bavarian Government, who were anxious to push forward the works. New mines were opened out, the whole district being known to be rich, and private enterprise was encouraged. The quality of the ore raised in 1814 was 14 per cent. of quartz, 48 per cent. of broken rock, 38 per cent. of slate, and the proportion of gold averaged 2·4 ounces per ton of quartz. In spite, however, of all efforts to raise the standard of work, the output remained as poor as before, only one-sixth that of a neighbouring stone-quarry. Improvements were made in dressing the ore, and in 1811 a company was formed to work a new gold-vein, but although it was economically administered, and every facility given to it by the Government, it ultimately failed. Tyrol next passed under the Austrian Government, and the mines were taken over by that State. Work by contract was then introduced, and proved the final ruin of the mines. All the best workers left, no proper supervision was exercised over those who remained, new shafts were not sunk, and the old were gradually abandoned. This was the more to be regretted because the ore increased in richness the deeper the workings were carried, but the gold was unequally distributed, and when a shaft was found to be poor it was left, instead of extending the works until a richer ore was reached. The deeper the mines were dug, the more difficult it became to get rid of the water, and in 1858, at the moment of signing a contract conveying them to another company, the pumping-engine broke down. Although they opened up a rich new vein, this company suddenly stopped after 10 years, the pumps fell into decay, and the mines were drowned. The failure was chiefly due to the poverty of the company, and to the great depth reached, the cost of pumping swallowing up all the profits. B. D.

THE BERGMANNSTROST MINE AT CLAUSTHAL, GERMANY.

Über die Gangverhältnisse der Grube Bergmannstrost bei Clausthal. *By* — TINKEL. *Glückauf*, 1897, *vol. xxxiii., page* 73, *with* 5 *plates.*

This paper contains a very detailed account of the vein system worked in the Bergmannstrost mine, which is situated upon the main Burgstädter vein of the north-western Harz, and works a series of ore-shoots that form a continuation of those formerly worked in the Dorothea mine, the latter having been exhausted in the year 1886. The depth is at present 850 metres (2,800 feet). The main vein dips here from 70 to 90 degrees to the south or south-west, and in addition to it three ore-shoots ("floors") are mined, two on the hanging-wall side known as the middle shoot and the hanging shoot respectively, and one on the footwall side known as the footwall or sparry shoot; as a general rule the width of the main vein is between 8 and 12 metres (26 to 39 feet). The country-rock consists of clay slates and

greywacke, belonging to the Kulm series of the upper Harz; the general direction of the strata is about north-north-east to south-south-west, and the dip 65 to 80 degrees south-easterly. The stratification has undergone marked deviation from its normal course in the neighbourhood of the vein-fissure, having been bent round sharply till its strike is about east to west. The fissure is filled mainly with shattered fragments of the wall rocks, which have been greatly altered and mineralized by the solutions circulating in the fissure. Barren rocks or "horses" of these country-rocks, which have been but slightly shattered, and therefore carry no ore, are also to be found; the mineral constituents of the gangue are chiefly quartz, calcspar and spathic ore, the valuable minerals being argentiferous galena, zinc-blende, copper pyrites, iron pyrites and zündererz (a variety of jamesonite—$Pb_4\ Sb_6\ S_{17}$). An important observation is that the amount of silver present in the ores is diminishing with increasing depth. Thus the lead in the ores (taken at 60 per cent.) showed a diminution in the percentage of silver as follows:—In the main Burgstädter vein, it diminished from 0·0889 to 0·0609 per cent. in an increase of depth of 26 metres (85 feet). In the middle shoot, it diminished from 0·0865 to 0·0522 per cent. in an increase of depth of 125 metres (410 feet). In the Bergmannstrost hanging shoot, it diminished from 0·0732 to 0·0467 per cent. in an increased depth of 261 metres (856 feet). The ores occur either massive or irregularly distributed, rarely in bands, more often in concentric layers known as ring- or cockade-ore. In the latter case, the kernel is a fragment of clay-slate or calcspar surrounded by layers of quartz, galena, and zinc-blende; the interstices between these masses are filled with calcspar or more rarely quartz. There are evidences that the fissures have been reopened after filling, but faults are very rare. H. L.

THE GOLD-MINES OF KOCHKAR, URALS.

Les Gisements d'Or du Système de Kotchkar dans l'Oural du Sud. By N. Wyssotsky. *Congrès Géologique International*, 1897, *Guide des Excursions, No. VI., pages* 1-6, *with map.*

This district lies on the eastern slope of the Southern Urals, about 50 miles south-west of Miass. It comprises something like 360 to 400 gold-deposits, all situated along the upper course of five small streams, the Kochkara, Chornaia, Osseika, Kamenka and Sanarka. Placers have been worked here from 1844 onwards, and as these became exhausted the gold-reefs discovered between 1863 and 1867 have been more actively exploited.

In the middle of a broad belt of granite, which runs parallel to the meridian, the rocks have undergone much dislocation and fissuring in a transverse direction, and the granite has been partly broken up and metamorphosed. The auriferous country-rock is berezite, a granite wherein the felspar is almost wholly replaced by quartz and muscovite: the gold-quartz veins (50 or more in number) appear to have arisen from the kaolinization of the granite, and form a network, the general strike of which is east-and-west to south-east and south-west.

The veins vary in thickness from 2 inches to 6½ feet or more; they pitch almost vertically, and consist of grey or greenish opaque quartz with inclusions and venules of mispickel, pyrites, stibine and galena. They are richest near the surface, and it is noticed that lower down the proportion of gold increases concurrently with that of mispickel. The average gold content is 100 to 200 grains per ton, and the gold contains about 30 per cent. of silver.

In most of the workings, so far, only the decomposed rock has been touched: it is easily broken up and treated by the amalgamation process. The decomposed rock sometimes extends down to a depth of about 180 feet; from this depth down to 450 feet or more the undecomposed [redacted] the auriferous material

being separated from the accompanying ores by the *stossherd*, or frue vanner, and then chlorinated or cyanized.

The author gives a short description of the Mitrofaniev, Gavriilo-Arkhangelsk, Woskressenski, and other deep-level mines, and then refers to the deposits of secondary origin. These belong to the type of placers *in situ*, or placers which are very little removed from their original point of formation, and they are mostly in intimate relationship with the quartz-reefs. In the largest placer of all, the richest portions run in a belt parallel to the outcrop of the reefs. The ordinary structure of these placers is as follows (in descending order):—Variegated stiff clay (barren), 13 to 40 feet; coarse sand with quartz and granite-pebbles, and gold in its lower portion, 1½ to 5 feet. The gold content varies from 20 to 160 grains per ton: this coarse sand is underlain by decomposed granite, containing much the same amount of gold. Some of the placers are recent, others date from Pleistocene times.

The paper is preceded by a bibliographical list. L. L. B.

PHENOMENA CONNECTED WITH THE ORE DEPOSITS OF THE LA CAROLINA AND SANTA ELENA MINING DISTRICT, SPAIN.

Fragen und Anregungen die sich an das Auftreten der Erze im Gangrevier La Carolina-Santa Elena (Spanien) knüpfen. *By* A. O. WITTELSBACH. *Zeitschrift für praktische Geologie*, 1897, *page* 5, *and illustration.*

The villages of La Carolina and Santa Elena are situated on the southern spurs of the Sierra Morena, respectively 18 and 25 kilometres (11 and 15 miles) north of the well known lead-producing district of Linares. The district consists of Palæozoic slate, with alternations of eruptive granite; both these rocks are traversed by two series of fissures, one a productive series, with a strike varying from north-west to west-north-west, and the other a series of cross fissures at right angles to the former, older than the latter, filled chiefly with quartz and country rock, and never worth working. The veins pass from granite to slate alternately without their course in strike or dip being in the least affected, although the nature of their filling is markedly so.

The next and most recent formation in the district is Triassic, patches of which overlie the others, but are nowhere traversed by the vein-fissures.

The principal ore is galena, often converted into cerussite in the upper levels; blende is rare, copper and iron pyrites more plentiful, the non-metallic minerals being chiefly quartz and barytes. The veins are chiefly filled with comminuted wall-rock, partly metamorphosed. In the granite, which is rich in felspar, the veins are filled with kaolin-like masses, known as *gredas*. The important point to note is that certain of the fissure-veins, *e.g.*, the Esperanza and San Gabriel veins carry lead-ores only in the granite, and become absolutely barren in the slates which they also traverse. In the granite, near to the boundaries of that rock with the slates, the veins suddenly become much richer than in the average of their course. On the other hand, the El Castillo vein, dipping southward like the others, and having a strike differing only 15 degrees from the former, together with some minor veins, shows exactly the opposite phenomena, that is to say, it is lead-bearing only in the slates, and barren in the granite. None of these alterations in richness are accompanied by any change of direction.

The silver content of the veins is somewhat variable, though a good deal higher than in the Linares district; the country-rock seems not to affect the richness of the lead in silver, although the latter appears here as in some other localities to become poorer in depth.

The author is unable to offer any explanation of the above phenomena.

H. L.

NATURE AND ORIGIN OF THE SEJA GOLD-DEPOSITS, EASTERN SIBERIA.

Die geologischen Entstehungsverhältnisse einiger Golddager. *By* P. Javorovsky. *Zapiski imperatorskavo S. Petersburgskavo Mineralogicheskavo Obshchestva*, 1895, *vol. xxxiii., pages* 307-351, *with figures in the text.*

The extreme importance of the part played by the tectonic character of the auriferous parent-rock in determining the formation of gold-deposits, their richness in ore, etc., was impressed upon the author in the course of his examination of the Seja gold-deposits, which rank among the richest in Eastern Siberia. The best portion of the Seja group comprises the localities situated on the right-bank affluents of the Ilikan, and of this portion of the area the author supplies a sketch-map showing that the rocks are gneisses and granites.

The first-named are traversed by numerous bedded quartz-reefs, whose breadth varies between a few inches and 13 feet or more. Most of the reefs are auriferous, but very poorly mineralized, averaging 2½ to 5 grammes per metric ton (or 0·09 to 0·18 ounces per British ton).

The granites, of a light-grey colour, are peculiar therein, that they are chiefly made up of nearly spherical quartz-grains, whereas the felspar appears to act, so to say, as the cementing-material. Consequently the slightest weathering of the felspar causes the rock to crumble away, and the quartz-grains, the biggest of which are of the size of a pea, are easily swept away by streams having a very low gradient of fall—a circumstance which has no small influence on the accumulation of the auriferous deposits.

In the district under consideration, the granite generally occupies the middle and lower portions of the river-basins, while gneiss crops out in the upper courses of the rivers.

The author then proceeds to describe the Chálon valley deposits which are worked by a company in whose service he was engaged in 1889 to 1890. The Chálon is a small, quietly flowing stream, about 5 miles in length, very different in character from the torrential water-courses which predominate in that area. The valley is fairly broad, sloping gently to the right bank, while here and there the left bank is a steep scarp. The physiography recalls that of many of the auriferous districts in the Southern Urals.

The auriferous deposits overlie the granite, from which they are separated by a bed of granite-rubble. They are gravels and pebble-beds, loosely held together by an argillaceous cement, and do not generally exceed 13 feet in thickness. In the main they are made up of *débris* of the gneisses, hornblende-rock, and quartz, granite-*débris* playing only a secondary part. In the upper layers, however, the latter crowd out the gneiss-pebbles, and at the same time the argillaceous cementing material increases in amount. While the gneiss-*débris* are well rounded and smooth, the granite-fragments are angular and rough-surfaced. The gravel and sand consist almost wholly of quartz-grains, which, by their form and the traces of adhering felspar, give evidence of their derivation from the granites.

The deposit is richest in gold at the bottom, and becomes poorer upwards, coincident with the increase in number of the granite-fragments as compared with the gneiss-pebbles. The uppermost layers have not been worked hitherto, as in practice only such layers are regarded as auriferous which yield at least 0·25 gramme per metric ton (or 0·009 ounce per British ton), and these are struck here at a depth of about 5 feet from the surface. It is known, however, that the gold is disseminated right through the deposits, from top to bottom.

As regards the horizontal distribution of the gold, that appears to be fairly regular within each area, but the yield from each washing depends upon its particular position along the stream. Thus, the sand from the middle course yields on an average 0·46 ounce per ton, that from the lower course rather less than 0·08 ounce per ton, and that from the upper course 0·21 ounce per ton. Taking a cross-section of a deposit, it is found that the central portion is often astoundingly rich in gold, and the author quotes such miraculous figures as 22·4 ounces, 89·6 ounces, and even 627·2 ounces per ton, but doubtless these are very exceptional cases. Despite the small dimensions of the gold particles, the very gentlest spraying with water shows the sandy working-face all bespangled with glittering flakes; and these being too small to pick out with the fingers, dishonest workmen have found it much simpler to steal the sand just as it is. A gloveful will yield as much as 1 or even 1½ ounces of gold. The average production of the entire deposit is small in comparison with the figures just quoted, because it includes the washings from all the portions worked, poor as well as rich. From the central portion outward, the gold content diminishes gradually in every direction, and this shows that here the auriferous concentration at a particular point cannot be referred to the usually assigned cause, namely, that where the gold lies thickest was the point of greatest activity of the current which formed the deposit.

The author draws attention to a peculiarity which may remind English readers of the Banket beds of the Witwatersrand, namely, that the gold either is most thickly accumulated immediately underneath the pebbles, or is fast cemented to them by an argillaceous substance which fills up all depressions in the under-surface of the pebbles. If a sample of the auriferous sand-and-gravel be taken, and the pebbles with their adhering cement be picked out, it can be proved that something like 50 per cent. of the total gold content is thereby eliminated. The origin of this cementing-material appears to be exemplified in an auriferous thin layer of silt or mud which is seen to underlie great masses of granite and other boulders at many spots along the banks of the Ilikan river (of which the Châlon is a tributary).

Along the Sanar, the Khorogachi, and the Chegdali rivers are gold-deposits similar to, but poorer than, those of the Châlon Valley. These water-courses run in steep ravines cut through the granite. In the deposits on the Horatius brook, on the other hand, the argillaceous cementing-material of the gneiss-pebbles plays an even more important part than in the Châlon gravels. The uppermost layers, too, are often rich in gold, and the metal occurs in a state of less fine division, nuggets being found up to 3 ounces and more in weight. The average production is 0·2 ounce per ton of material washed. Lastly, in the Chalta Valley, the gold is more widely disseminated than elsewhere in this area.

The author then proceeds to discuss the question of the parent rock whence the gold of the Seja region was primarily derived. Everything points to the gneiss. To confirm this conclusion, the author made a careful survey of the ground. It was noticeable that everywhere over the surface of the granite gneiss-boulders of various dimensions lay scattered around, and at last he discovered a spot where highly weathered hornblende-gneiss was exposed *in situ* overlying the granite, and filling up the bottom of a small synclinal. On the north, this outcrop is fringed by a zone of gneiss-rubble, and samples of this latter yielded on assay a considerable amount of gold. Plainly, the granite was at one time completely covered over by the gneiss. That no gold is present in the granite itself was proved again and again by crushing and assaying samples of the rock, and this at a spot where the miners at first sight appeared to have struck a gold quartz-vein in the hitherto barren granite, while a careful examination showed that the vein was really enclosed in gneiss, faulted in among highly-disturbed overthrust granite.

The tectonic relationships of the area may be summarized as follows:—A highly compressed anticlinal fold, with a granite core and limbs of gneiss, was, at the moment of dislocation, fractured along the bedding-planes, and the fissures were subsequently infiltrated with auriferous quartz. At a later period, secondary folding and intense faulting took place, with the result that the gneiss and the associated quartz-reefs were let down to a considerable depth.

Various points in connexion with the distribution and habit of the gold in the placers, such as the origin of its flakiness and shagreened surface, its association with the pebbles, and the relation between the progress of valley-sculpturing and the lessening in size and quantity of the auriferous particles floated down, are then considered in great detail; and the author attaches much importance to the conclusion that rich gold-placers are by no means necessarily derived from a highly auriferous parent-rock. Given the necessary geological conditions, rich deposits may originate from the erosion of a rock comparatively poor in gold.

The deposits herein described appear to the author to demonstrate the need of expanding Prof. Von Cotta's classification of placer-deposits, which lays too much stress on the travel of the gold and its associates in one particular direction. In their journey down the valley from their place of primary origin the auriferous particles moved in three directions: (1) vertically, (2) horizontally, across the valley, and (3) horizontally, along the valley. He proposes the following extended classification:—

I. Alluvial gold-deposits:—(1) *Stricto sensu;* (2) Detrital deposits.

II. Sunken gold-deposits formed *in loco*:—(1) On the parent-rock or matrix; (2) On a bed of foreign rock.

III. Deposits formed from drifted material:—(1) In river-valleys; (2) In the sea (?).

IV. Mixed gold-deposits.

The author defines as *alluvial*, properly so-called, those deposits wherein the materials derived from the erosion of the parent-rock have received no further enrichment from the water flowing to them, and as *detrital* those which have been so enriched. *Sunken* gold-deposits are those where the gold and its associates have by reason of gravity reached the bottom of a stream-bed too fast to travel any appreciable distance. On the other hand, those formed from *drifted* material are accumulated at some distance from their point of origin; and the term *mixed* gold-deposits applies especially to those along mountain-rivers and streamlets which partake of the characters both of the *sunken* and *drifted* deposits.

L. L. B.

GOLD-FIELDS OF TRANSVAAL AND CHARTERLAND, SOUTH AFRICA.

(1) *Études sur les Champs aurifères de l'Afrique du Sud.* *By* ALBERT BORDEAUX. *Revue Universelle des Mines*, 1897, *vol. xxxvii., pages* 1-67, *with* 2 *plates.*

The geological formation of the Transvaal is simple, consisting of strata of schists, quartzites, grits and conglomerates overlain by a dolomitic series with siliceous sands and argillaceous schists, interbedded with lenticular masses of coal. All these strata lie upon granite which crops out over large areas of country especially on the north, the south-east, and the central plateau of Charterland. The general direction of all the stratification takes the form of almost concentric arcs, whose centre lies in Basutoland.

Whilst the general arrangement of these strata is fairly regular, local disturbances are of but little importance, and consist in intrusions of various forms of greenstone that have penetrated even the granite.

The most important fold appears to have upheaved, subsequently to a portion of its deposits, the whole system on the north and south, at the Zoutpansberg and the Witwatersrand, and to have brought about intense erosive action by exposing to the air and water enormous masses of quartzose and felspathic rocks. This fold appears to explain the fact that none but quartz-pebbles are found in the conglomerates, the sandstones, and the quartzites, the disintegrated granites having only left behind their quartz elements. Moreover, the granites also appear on the north of the Transvaal, in the whole central region of the Charterland, forming what may be called the backbone of South Africa, and showing evidence of powerful erosive action. The altitude of the Charterland granites varies from 4,500 to 5,500 feet, being thus equal to that of the Transvaal sedimentary deposits; but the altitude of a portion of these latter is due to an upheaval the amplitude of which is still difficult to determine, while it may be admitted that the sedimentary deposits began in the less elevated regions of the central plateau. As one descends this granite-plateau, either on the east or on the west, the effects of erosion are more and more manifest; and the valleys are formed, first in the sediments, and then in the granite itself which is laid bare, while the face of the country assumes the characteristic aspect of South Africa, being studded with hills formed of granite-blocks.

The basin of the Witwatersrand appears to form a huge synclinal, the axis of which runs about east-north-east to west-south-west. It rests upon granite, and consists of the following formations:—(1) Schists, known as Letaba schists. (2) Grits, quartzites and schists, without conglomerates; one of the beds of schists is characteristic and is called the Hospital Hill schist. (3) Grits, quartzites and schists, with auriferous conglomerates, coeval with the grits and conglomerates of Table Mountain. (4) Dolomitic limestone series, unconformable to the foregoing. (5) The series of schists, grits and quartzites of Magaliesberg and Gatsrand, enclosing lenticular deposits of coal, some of great thickness.

The author proceeds to describe the system of reefs in detail, and draws the following general conclusions:—(1) The richness in gold of the reefs is independent of the amount of pyrites they contain. (2) The average yield does not diminish in depth. (3) The yield increases simultaneously in the different reefs of the Main Reef series in the various zones of the Rand. (4) There is no gold in the conglomerates without cementing-material, called Bastard Reefs; the pebbles in them appear to be barren. (5) Pebbles of quartz carrying gold, and some of them rich, have, however, been found in several reefs. (6) Crystallized gold has been found in several mines, due to a redeposition of the gold in the fissures of pebbles or about their surfaces. (7) Rich shoots exist, sometimes nearly vertical, at others more nearly horizontal, cut off by faults or dykes. (8) The line of the reefs, even in the central portion of the Rand, is far from being well defined or continuous. (9) Rich deposits should rather be looked upon as zones in the entire series of grits, quartzites and conglomerates. (10) The flatter a reef lies the poorer it is; this effect is not, however, produced in depth. This seems to be a proof that the steep pitch of the reefs was produced after their formation, but that this formation itself took place at various angles, the steeper of which were the more favourable to the existence of gold. (11) A reef often passes into the surrounding quartzite, which then becomes auriferous. (12) Veins of secondary quartz, at times some inches in thickness, are abundant in the banket itself. (13) A selvage of clay often occurs along the walls of the reefs, due perhaps to the attrition of the pebbles of the upper conglomerate. (14) Zones of local impoverishment appear in depth analogous to the characters of the outcrops. (15) Near certain faults the reefs are seen to bend,

and apparently penetrate into the faults. These faults still cause an infiltration of water, and may have done so from the first. (16) The ore is locally stratified, especially in the hollows of the curves of the Black Reef. (17) Horizontal throw of the reefs is sometimes combined with vertical throw. (18) There are numerous small slips in the reefs, very often parallel in the undisturbed portions, at times concentric in the folded or disturbed portions. (19) Pyrites sometimes occurs in disseminations separated by empty spaces, more often in compact masses, in which gold can be seen under the magnifying glass. (20) Pyrites is the only abundant mineral present, though others occur exceptionally. (21) The cementing-material contains chlorite, cyanite, steatite, serpentine and mica, all appearing to be derived from the remains of micaceous granite. (22) In some reefs, the quartz-pebbles have a curiously flattened shape. (23) The dykes consist of a hornblendic micaceous diorite, various diabases, olivine-norite, or basalt; a few zeolites have been found in placers. (24) Some of the eruptive rocks are auriferous. (25) It seems probable that the gold is of secondary origin, brought about after the deposition of the conglomerates by the intrusions of eruptive rocks; these have made their way along planes of fissure or of faulting. (26) The gold is generally crystallized in cubes or in flat scales. (27) The richest zones seem to be those where the greatest amount of dislocation has taken place.

Neither at Klerksdorp nor at Heidelberg is there any series of reefs that may be compared with those of the Witwatersrand, either in extent or value; and there are only exceptions which have yielded, or which appear as if they ought to yield results worthy of a working, and even then over sufficiently restricted areas, as is the case with Eastleigh at Klerksdorp, with Nigel, and perhaps with Heidelberg-Roodeport and with Molyneux at Heidelberg. H. L. AND J. W. P.

(2) *Etudes sur les Champs aurifères de Lydenburg, de Kaap et du Charterland, Afrique du Sud. By* A. BORDEAUX. *Annales des Mines*, 1897, *vol. xi., pages* 273-349, *and* 3 *sketch-maps.*

The author has studied the above-named three gold-fields and gives the result of his observations.

De Kaap and Komati.—These two river-valleys are approximately parallel, both entering the Crocodile river. The geological formation is among the most ancient of South Africa. The base is formed of coarse-grained granite, syenite and pegmatite, whilst the hills that separate the two valleys consist of schists, quartzites, conglomerates and sometimes of fissile clay-slates, with a general east-and-west strike, subject to numerous dislocations, so that the strike is even at times north-and-south. These bedded rocks attain no great importance except in the Makongwa mountains, at the angle of which stands the Sheba Hill, and where their thickness exceeds 10 miles. This belt of stratified rock is continued eastwards in a narrow strip on Moodie's, another narrow strip running from North Kaap to Barrett's Berlin and Cootjestroom. All these rocks are traversed by dioritic dykes. Gold exists indifferently in all the stratified rocks, but this auriferous impregnation is confined to narrow belts from 100 to 500 feet in width, though often of great length; each such belt may contain one or several auriferous lines, one of which only is, as a rule, workable. True fissure-veins do not seem to occur; there has, rather, been an impregnation of gold through the planes of fissure, as on the Rand; veins and pockets of quartz, often auriferous, have thus been produced. The quartz is often black, which colour may be attributed to the presence of bituminous particles which possess the property of precipitating gold.

The Barberton gold reefs form five groups, namely, Three Sisters, Sheba Hill,

North Kaap, Barberton and Moodie's. The Sheba mine on Sheba Hill is the oldest and most celebrated mine in the Transvaal. The formation here strikes east-and-west, and dips 50 to 62 degrees to the south. The succession of strata from north to south is as follows:—(1) Blue bar, consisting chiefly of talcose schist carrying pyrites and free gold; (2) reef, consisting of quartzite with bunches and veinlets of black quartz veined with white, the black carrying the gold and the white being quite barren; (3) very dark quartzites; (4) schistose slates; (5) conglomerate, a true banket, carrying a few pennyweights of gold to the ton; and (6) schistose slates of country-rock. The Sheba reef thus consists of ramifications of black quartz in a bed of quartzite; and, generally speaking, it seems to get narrower on going downwards. The auriferous portions form shoots; the main shoot worked in the Sheba is 40 to 70 feet thick and 260 to 400 feet long. It dips with the quartzite to the south, and also dips 70 to 75 degrees to the west. The mineralization is due to the numerous outbursts of diorite. The other gold-bearing shoots on this line are much smaller and poorer.

In the North Kaap, there are reefs of arsenical pyrites carrying gold at the Consort, and various reefs of little importance, *e.g.*, at the Albion, North Sheba, etc. At the Kantoor, a bed of conglomerate has yielded about 4 dwts. of gold to the ton; at Barrett's Berlin, deposits of gravel carrying coarse nuggets, showing traces of crystallization, are worked.

About Barberton, there are numerous reefs of black quartz like that of the Sheba, but the deposits are not permanent, and of little importance. At Moodie's, the reefs are of very white quartz in green chloritic schists; there are two gold-belts, one on the north containing the Pioneer reefs, and another on the south traversed by the Ivy reefs.

In Steynsdorp and Swaziland, the formation is like that of De Kaap; the reefs are of white quartz in schist, but are even less permanent or continuous than on Moodie's.

Lydenburg and Pilgrim's Rest.—Much alluvial has been worked here, notably in the Blyde valley. The district consists of a series of grits, sandstones, schists, conglomerates and quartzites, intercalated with dolomite, the latter formation carrying the gold in veins of "rotten" saccharoidal quartz. The most important is the Theta reef at Pilgrim's Rest; Mac-Mac, Spitzkop, and Watervaal are the other gold-fields of the district, at all of which alluvials have been worked; veins are also known, but three-fourths of the gold comes from the reefs of Pilgrim's Rest.

Rhodesia or Charterland.—The general formation is granite and metamorphic gneiss, traversed by belts of schist running generally north-east and south-west, and traversed by numerous dykes of eruptive rock. The gold-bearing zones are generally confined to the schists which are chloritic or micaceous, and traversed by veins of quartz. A little gold is also found in diorite, and even in certain granites. The reefs may be divided into four classes:—1. Contact-veins between metamorphic schists and diorite or granite. 2. Fissure-veins in granite, usually superficial. 3. Fissure-veins in the schists generally parallel to the foliation, more rarely crossing it. 4. Impregnation of diorites or of kaolin resulting from the decomposition of diorite.

In Manicaland, a few reefs are known, *e.g.*, Guy Fawkes, Lion, Rezende, Penhalonga, Champion, Grand Duke, etc. On many of these, ancient workings have been found, but little work has yet been done, and some of the reefs seem to pinch or cut out in depth.

In Mashonaland, the Salisbury and Enterprise district is the most advanced, there being a five-stamp battery working on the Salisbury reef; many of the reefs seem to be pyritic.

In the Mazoe district, there are a large number of reefs, but there are no developments worth mentioning, though there are numerous ancient workings.

The principal mine of the Le Mogundis district is the Ayrshire, opened on a dyke of auriferous diorite, assays of which show, however, more silver than gold; fine specimens of diorite, enclosing lumps of free gold, have been found. There are a number of old workings and of quartz-reefs in this district, such, for instance, as the Mandora, which is generally poor, though with rich patches.

In the Hartley Hills district, there is only one five-stamp battery at work; several reefs are known, but have been but little worked; in some places, surface-crushings have given high returns.

In the Victoria district, there are many reefs, but these do not seem to have carried as well in depth as their outcrops promised.

In Matabeleland, the reefs and formations are similar to those of Mashonaland; numerous concessions have been taken up, but little work has been done so far.

The author's general conclusion is that though the generality of the reefs are of little value on account of the geological conditions of Charterland, it is yet probable that in some points, where old workings are extensive, but have either been imperfectly explored or not explored at all, reefs of sufficient size and value to be worth working on a serious scale may yet be met with. Transport is at present the great difficulty, but in the future a large portion of Charterland will be valuable for agricultural and pastoral purposes. H. L.

(3) *Ueber die Goldvorkommen im Lydenburger District.* *By* J. KUNTZ. *Zeitschrift für praktische Geologie*, 1896, *page* 433, *and* 10 *illustrations.*

Lydenburg.—The Lydenburg gold-field was the first known of the gold-fields of the Transvaal, though its development has been less rapid than that of the Witwatersrand. It lies in the Drakensberg range, the geological sequence of formations being the following from below upwards: –

Granitic rocks form the basement-rocks, and occupy the low country, above which rises quite precipitously the Lydenburg Sandstone, or lower sandstone, containing occasional beds of conglomerates (not auriferous) and slates. Above this lies the dolomite known as Olifantsklip to the Boers; it is a dark bluish-grey crystalline rock, some 500 feet to 800 feet thick, containing numerous bands of an amorphous or cryptocrystalline quartz generally called hornstone. Thin beds of slate also occur, especially near the top and bottom of the formation, as also do occasional sheets of greenstone, which is generally decomposed into a clayey mass.

Above the dolomite lies the upper sandstone formation, consisting of a series of alternate beds of fine-grained sandstones and sandy slates, traversed by diorite dykes which occasionally form sheets intercalated in the stratification.

All the workable occurrences of gold in the district have been confined to the dolomites, which crop out over a width of some 2 miles. These comprise the deposits known as the Glynn reef, Frankfort reef, Clewer or Morgenzon reef, Beta reef, Theta reef, Chi-Psi-Nu reef and Jubilee reef.

These deposits all consist of crystalline, cellular, porous saccharoidal quartz, yellowish to brownish where rich in gold, hard and white where poor. The ore is often intermixed with slate and with a manganiferous earthy substance (mud); there are at times partings in the ore consisting of slate, dolomite, hornstone, earthy mud, or more rarely decomposed greenstone. The gold is very finely disseminated, very rarely visible to the naked eye, and the richness of the deposits varies from traces to 40 ounces to the ton.

The deposits are very variable in thickness, sometimes wedging out entirely, sometimes over 10 feet thick. The general lie of the deposits is almost horizontal with a slight dip to the westward, but continuous minor undulations occur forming alternate basins and saddles, whilst near their outcrops on the hill-flank the strata are bent downwards sharply. The roof is generally extremely bad and requires much timbering. The various reefs occur at different horizons in the dolomite, the Glynn reef being only 100 feet above the base of the bed, whilst the Jubilee reef has for its roof a hornstone-bed about 20 feet thick that is immediately overlain by slates. The Theta reef, too, lies under a bed of hornstone which is directly underneath the lowest beds of the upper sandstone, whilst there are above the Beta reef some 65 to 80 feet of dolomite containing no other deposits; it is difficult to say whether these two last-named, which are separated from each other by a valley, really form one deposit or not. It has been observed that the Beta reef is richest in the neighbourhood of the greenstone-dykes that traverse it; and thin slaty partings in this reef are also generally very rich in gold.

The general method of mining is by bord and pillar, the latter being left some 50 feet square, but is irregular, corresponding to the irregularities of the deposits. The ores are treated by crushing in stamp mills and cyanidation, water-power being abundant.

There are various opinions as to the mode of formation of the deposits; they are sometimes looked upon as bedded veins, but the appearances do not seem to favour this view; neither can they be original members of the formation. They do not seem always to lie strictly parallel to the stratification, both roof and floor being very irregular. It is probable that flat hollow spaces have been formed by the solution of the dolomite, and that these spaces have been subsequently filled with other materials, mainly auriferous and ferriferous quartz, by some change in the chemical character of the solutions. This assumption renders it probable that the deposits will not continue in depth, *i.e.*, below the permanent water-level.

Another mode of occurrence of gold quartz in the dolomite is that of the so-called "diggers' leaders;" these consist of a great number of stringers of quartz that traverse the dolomite in places, and especially the lower strata; these stringers vary from the thickness of a sheet of paper to about 6 inches, and are on the average 50 feet apart, and traverse beds of slate, sandstone, dolomite, and decomposed greenstone; they are barren in the last-named, poor in the dolomite, carry 1 to 3 ounces to the ton in the sandstone, and 10 to 30 or even up to 50 ounces in the slate. They are only rich in the neighbourhood (say 200 feet on either side) of an older greenstone dyke and are cut off or thrown by a more recent one.

In the upper sandstone-formations, reefs have been worked similar to those already described, but have never given satisfactory results. H. L.

(4) *Étude Technique sur les Mines d'Or du Witwatersrand.* *By* LEON DEMARET. *Annales des Mines de Belgique*, 1897, *vol. ii., pages* 2-88, *with plans, sections, and drawings.*

Witwatersrand.—Between Pretoria and Johannesburg, there emerges a large granitic mass of elliptical form, the axis of which, bearing east and west, forms an anticlinal. On the north of Pretoria, the strata resting on the mass of granite dip towards the north; and on the south, at Johannesburg, they dip towards the south, then form a synclinal, and again rise, to crop out at the Vaal river with the dip to the north. This synclinal contains the seams of conglomerate that are now worked, which consist of quartzose elements neither pyritiferous nor auriferous, connected by a siliceous cement both pyritiferous and auriferous. The axis of the synclinal bears north-east and south-west; and on following the granite-mass

towards the south the following rocks are found:—(1) Granite and gneiss; (2) Quartzites and white sandstones; (3) Schists, fine ferruginous sandstones and quartzites; (4) Quartzites and auriferous conglomerates; (5) Dolomite; (6) Gatsrand and Magaliesberg quartzites, and (7) Karoo deposits, which contain seams of coal varying from 2 feet to 21 feet in thickness.

The auriferous conglomerates comprise the following "reefs" or seams (in an upward direction) *e.g.*, from north to south starting from Pretoria:—(*a*) Rietfontein reef; (*b*) Main reef, including the North reef, Main reef proper, Main reef leader, and South reef; (*c*) Bird or Monarch reef; (*d*) Kimberley or Battery reef; (*e*) Elsburg reef; and (*f*) Black reef. These seams were formed at the bottom of a sea into which the continental rivers hurried along the pebbles and sands washed from the mountains, this being a littoral formation deposited in strata originally horizontal; but the movements of the earth's crust and granite-eruptions have subsequently folded them into a synclinal, the axis of which is approximately east and west, while to the north of it is an anticlinal. The opinion of some authorities that the quartz, which alone constitutes the pebbles, does not necessarily proceed from veins containing quartz alone, but may be due to quartziferous rocks of which the other elements than the quartz have been triturated and carried away, is not endorsed by the author, who considers it more logical to suppose that these pebbles were simply formed by the destruction of quartz-veins.

The various theories for explaining the presence of gold in the conglomeratic strata are summed up in the following terms, to each of which are added the arguments for and against:—(*a*) The conglomerate-seams are only solidified placers, being due to the erosion of pyritiferous and auriferous quartz-veins. (*b*) The gold and pyrites dissolved in sea-water have been precipitated by decomposed organic matter at the same time as the strata of quartz-pebbles were formed. (*c*) The pyritous and auriferous impregnation was subsequent to the deposit of the conglomerate-seams. (*d*) The conglomerate-seams have a fluvial origin.

The first mines opened were naturally those on the outcrop, and were worked either by slants into the seam or by small vertical shafts. When the continuance of the deposit in depth was proved, fresh concessions were taken up to the south of the former; and access was only obtained to these deep levels by vertical shafts.

The concessions are included in three zones roughly parallel and bearing east and west, viz., the northern zone of 2,000 feet mean width, comprising 70 outcrop mines, in which gold has been proved by actual working, and of which one-half now produce gold, while the other half will soon do so; the second zone, varying from 1,000 feet to 4,000 feet in width, now comprising 12 deep-level mines, six of which have not only proved the deposit worked in the outcrop mines, but are carrying out preparatory workings, or have actually begun to work; and the southern or third zone, that of the extreme deep levels, the width of which cannot yet be assigned, the deposit being at present only known by borings.

The author then describes the claims with the estimated quantity of ore per claim; gives the depths of the shafts in the deep-level mines; deals with the persistence of ore-seams in depth, and also that of the ore's richness in depth, with the limit depth of working, and, by way of example, the expenses of winning the Geldenhuis Deep mine.

He sets forth the following conclusions:—The persistence of the ore in depth, while preserving the mean richness in the basin, is ensured by the stratified nature of the deposit, by the deep workings of the outcrop mines and by the shafts and bore-holes in the deep levels; but, inasmuch as the workings in the outcrops have shown that the deposit comprises rich, moderately rich, and poor regions, one

must expect to find these three classes of regions in the deep levels. Moreover, as the dimensions of these various regions are unknown, it must only be considered probable, and not certain, that a deep-level mine is rich because situated to the south of a rich outcrop mine, or that deep-level mines are poor because a shaft or bore-hole, sunk at an isolated point, may have passed through poor ore.

J. W. P.

(5) *Ueber den Einfluss der Eruptivgesteine auf die Erzführung der Witwatersrand-Conglomerate und der im dolomitischen Kalkgebirge von Lydenburg auftretenden Quartzflötze, nebst einer kurzen Schilderung der Grubenbezirke von Pilgrim's Rest und De Kaap, Transvaal.* By PAUL R. KRAUSE. *Zeitschrift für praktische Geologie*, 1897, *pages* 12-25, *and* 1 *plate and* 9 *figures.*

Witwatersrand.—The character of the Witwatersrand formation is being studied by means of bore-holes and deep-level mines, whilst the mode of origin of the gold in the conglomerates has been comparatively neglected; various theories have, however, been put forward, according to some of which the gold existed in the constituents of the conglomerates even before the latter were formed, whilst according to others it was deposited during and according to some others, after their formation.

With regard to the first view, which was the original one, it has been shown repeatedly that, with the exception of one or two doubtful examples, the pebbles contain no gold, this metal being concentrated in the cementing-material. Seams of rolled pyrites or pyritic sand are said to have been noticed in places, but this fact, if established, would only prove that the cement included minute quantities of previously crystalline mineral matter. The gold, however, is very finely divided, and is in intimate mechanical but not chemical connexion with crystallized pyrites. This view, however, that the Witwatersrand conglomerates have been formed by the disintegration of gold-bearing quartz-veins has to-day been pretty well given up, even by its former advocates.

The second theory is to the effect that, simultaneously with the deposition of the sands and gravels, a continual process of precipitation from sea water was taking place. This view suffers, however, from a mass of internal contradictions; thus, the formation of beds of conglomerate extending for hundreds of miles could only have been produced under the action of violent currents, which would surely prevent a quiet and continuous precipitation from solution. Again, how can the fact be explained that such precipitation only enriched the conglomerate-beds lying at considerable vertical distances apart and not the strata of sandstone that alternate with them.

This theory seems, therefore, not to be tenable, hence we are brought to the third, namely, that mineralization was subsequently produced by metalliferous solutions ascending from the interior of the earth. The ascent of these enriching vapours and thermal waters was probably connected with outbursts of eruptive rocks. These eruptions must have been almost simultaneous with the elevation of the granite, and the molten rocks apparently found their way originally through the fault-fissures, and afterwards either broke through the strata or else made their way between the latter.

The three arguments that have been adduced against this view are:—(1) The rounded and apparently rolled pieces of pyrites to which reference has already been made. (2) The circumstance that all the conglomerates are not equally mineralized. (3) The circumstance that ores are said to be poorer rather than richer in the neighbourhood of the eruptive dykes, and that no direct connexion can be traced between the dykes and the mineralization of the conglomerates.

With regard to the second theory, it may be observed that the varying richness of the conglomerates may be explained by the variability in their permeability. All the conglomerate-reefs are mineralized and carry some gold, and it is currently held that the reefs with coarse pebbles and smoke-coloured or bluish-grey cement are the richest; this seems to show that those beds are the richest in which the widest interstices were filled exclusively with cementing-material.

As to the third theory, the only direct evidence of the connexion between the mineralization of the conglomerates and the eruptive rocks is to be found in the presence of talc and chlorite in the cementing-material, whilst these minerals do not exist in any of the wall-rocks. It is in nowise proved that the reefs are poorer in the neighbourhood of the eruptive dykes, whilst the author knows of several cases where exceptionally rich ores were found in immediate contact with them.

Lydenburg.—The best proof of the influence of eruptive rocks is to be found in the Lydenburg district, and notably at Pilgrim's Rest. The dolomite formation, interbedded with sheets of trap, is practically a reproduction of the classical formation of Derbyshire, except that the beds of galena of the latter are replaced by auriferous bedded deposits of quartz. The dolomites of Lydenburg rest upon clay-slate and this upon sandstone, the lower beds of which contain the deposits of coal, which outcrop to the south of Middelburg. There are numerous sheets of trap interbedded with the dolomite, and occasional bedded deposits of quartz which are rich in gold near the trap-rock, and chiefly where this rock is much decomposed. The various gold-bearing quartz-beds do not occur at the same levels in the dolomite formation.

De Kaap.—The De Kaap district consists of sedimentary formations, striking about east-and-west with a steep dip to the south, and are bounded to the north and south by granites; they consist, from foot to hanging-wall, of chloritic slates, quartzites, clay-slates, conglomerates and sandstones; conglomerates being, however, rare. Near the centre, the entire formation has been violently heaved towards the south, a phenomenon, no doubt, connected with the occurrence of eruptive rocks at this point. This break divides the field into two parts, the Sheba district in the east and Moodie's in the west. On Moodie's, the veins run near the contact of eruptive rock with chloritic schists, and consist of milk-white quartz carrying free gold, threads of auriferous pyrites, and in places gold-bearing tellurides.

In the Sheba district, the Sheba mine is the only one of any importance. The district is characterized by numerous bars of quartzites that form either the foot or the hanging-wall of the auriferous deposits. All the strata are here traversed by numerous north-and-south cross-veins, apparently fissure-veins, and the author thinks that these, though not themselves rich, form pay-shoots where they intersect the bedded deposits. The shoot of the Sheba is about 165 feet along the strike, and its real thickness is not yet known, for although its hanging-wall is well marked by a heavy bar of quartzite, explorations on the foot-wall side are constantly revealing additional belts of rich ore. Other mines in this district that may do well in the future are the Swartkopjes and the Woodstock. It seems probable that the masses of granite to the north and south unite in depth, and thus form a basin limiting the workable quantity of these deposits, but only at a very considerable depth. H. L.

(6) *Ein Beitrag zur Kenntniss des Umtali-Districtes (Manica, Mashonaland).* *By* Dr. K. A. Redlich *and* A. v. Dessauer. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1897, *vol. xlv., page* 1, *and plates.*

Umtali, Mashonaland.—The geological structure of the Umtali district consists of steeply inclined layers of Primary slates, probably coeval with the Swazi schists, striking from east to west for a length of some 60 miles along the Sabi river; the

belt is about 10 miles broad at the extreme east, but wedges out in the west, passing on the north into granite. Parallel to the slates, basic massive igneous rocks occur; both formations are traversed by greenstone-dykes and felspar-porphyries; serpentines and quartz-porphyries also occur.

Three types of quartz-veins occur, all parallel to the stratification and gold-bearing:—(1) Veins in talcose (or other) slates; *e.g.*, the Penhalonga reefs, characterized by the occurrence in them of crocoisite, the Revue, Champion, Grand, etc., reefs; (2) veins at the contact between granite and slate, *e.g.*, the Agency, Grand Manica, Quagga, etc., reefs; and (3) veins in basic rocks, *e.g.*, the Rezende, Orphan, Princess May, etc., reefs. The future prospects of this district seem to be developing satisfactorily. H. L.

(7) *Une nouvelle Théorie sur l'Inclinaison des Couches aurifères au Witwatersrand. By* F. SCHIFF. *Le Génie Civil*, 1896, *vol. xxx., pages* 87-89, *and sections of mines.*

Witwatersrand.—The beds of auriferous conglomerate which constitute the stratification of the Main reef series owe their industrial value to their regularity in the mines worked on the outcrop; but it was afterwards found that their continuity was interrupted in places by faults and dykes. Mr. Carrick lately pointed out in a communication to the Geological Society of South Africa that these fractures result from forces, the nature and direction of which may be determined with greater or less exactitude by an examination of the relative positions of the fault-planes and the seams surrounding them. The author reproduces Mr. Carrick's arguments, and gives nine sections of gold-mines, concluding that it would be easy to multiply such examples as appear to bear out the hypothesis advanced.

J. W. P.

GOLD DEPOSITS OF MADAGASCAR.

L'Or à Madagascar dans le sud de Betsileo. By C. CHAUVEAU. *Le Génie Civil*, 1897, *vol. xxxi., pages* 5-8, 20-22, *map and sketches.*

Although Madagascar has long been known to produce gold in moderate quantities, the greater portion of it was obtained by forced labour, or by irregular native work, under conditions that would not be possible in modern methods. Of the geology of the island only the outlines are known; the entire central portion consists of red, rather friable earthy rock, evidently of eruptive origin, and doubtlessly due to the slow decomposition of a felspathic and hornblendic rock. This is traversed by important outbursts of granite and by basaltic dykes, and is overlain by strata of Jurassic, Cretaceous and Tertiary age. Gold is widely distributed throughout the island; the only other known mineral deposits so far are an unimportant copper-mine near Ambositra, some deposits of galena, the outcrops only of which are known, a thin bed of lignite of Jurassic age at Amboratoby, and wells of bitumen discovered near Ambohitsalika. No Carboniferous strata have been met with, and there is accordingly no prospect of finding any true coal.

The district of Betsileo seems to be the most important as a gold-bearing district: the auriferous deposits consist of alluvials and of disseminations. No vein of gold-quartz has yet been met with, and all the quartz-pebbles occurring in the alluvials are barren, carrying neither sulphides nor free gold. The alluvial deposits form the bottom of river-valleys, and also the beds of actual streams. The gold is always very fine, none bigger than a pin's head having been found. The section of these deposits is generally similar: the gold-bearing sands and gravels are overlain by layers of clay and a bed of peat, and rest often upon a bed

Some mills save as much as 90 per cent. of the assay value, but in the majority not more than 75 per cent. is recovered. The total product of gold cannot be stated accurately, but it is estimated to be over 50,000 ounces per annum.

The country rock (known locally as "Bed Rock") consists of slaty sedimentary rocks, together with diabases and porphyrites, with enormous intrusions of coarse-grained granitic rocks. Many parts have a pre-Cambrian aspect, although it is certain that they are of much younger age. No fossils have been found in the sedimentary rocks of the district. The Carboniferous strata doubtless predominate, but there are also deposits of the later Jura-Trias period. The forming of the mineral veins was the last phase of the Mesozoic evolution. During the later part of the Neocene period volcanic material began to pour down through the valleys, and ultimately a sheet of lava covered the whole district. During this volcanic period the Sierra Nevada was subjected to a tilting uplift which at the summit probably amounted to several thousand feet, and the streams at once began the work of cutting into this desolate lava-plateau. In the district described in this folio, the sloping ridges—Harmony ridge and Banner-Hill Towntalk ridge—are the only remnants of the lava-sheet which once covered the whole region, while the present watercourses are sunk several hundred feet below the Neocene surface. Underneath the remaining portions of the lava sheet, the channels of the Neocene rivers have been found, containing in many cases important deposits of auriferous gravel.

A detailed geological examination of the district has been made, and the author gives a very minute description of each formation.

The ore occurs in fissure-veins, and the gold is found in pay-shoots of an irregular form. When the shoots are small they are called pockets or chimneys. The pay-shoot usually pitches at a steep angle on the plane of the vein. The following law appears to govern the general direction:—The shoot will, as a rule, pitch to the left of an observer standing on the apex of the vein, and looking down in the direction of the dip.

No relation can be established between the direction of the pay-shoots and the direction of the striation on the walls. Some of the veins pinch out at varying depths, but others continue to the deepest levels. The pay-shoots do not all come to the surface. For instance, a small shoot of ore was recently found at the bottom of a shaft 2,200 feet deep. Observations in a mine, at a depth of 1,523 feet, showed a temperature of 66° Fahr. in a damp bore-hole, and the air in the stopes had a temperature of 69° to 70° Fahr. The average annual temperature at the surface is supposed to be about 59° Fahr., but at 30 feet below the surface the temperature of the rocks was 53·5° Fahr.

The folio closes with a detailed description of the mines in the district, illustrated by numerous plans and photographs. R. W. D.

GREAT MOTHER LODE OF CALIFORNIA.

By HAROLD W. FAIRBANKS. *The Engineering and Mining Journal* [*New York*], 1896, *vol. lxii., pages* 248-250, *and map.*

The map given shows the course of the lode from Eldorado county to Mariposa. If we examine a geological map of the Sierra Nevada we see that, beginning in Mariposa county and extending northward until covered by the volcanic rocks in Plumas county, there is a widening belt of slates with associated dykes of eruptive rocks which are known as the Bed Rock series. Gold-bearing quartz-veins occur over much of this area, and these can be separated into three general divisions, the lower, middle, and upper belts. The middle one is the most regular and con-

tinuous, and by far the most productive through most of the counties on the western slope of the Sierras. It is the one to which custom is almost unanimous in assigning the term "mother lode."

This lode may be defined as a mineralized zone of varying width, sometimes reaching over a mile, and extending continuously through the counties of Mariposa, Tuolumne, Calaveras, Amador and El Dorado, and possibly farther north.

As far as can be learned, the term "mother lode" was first applied to the veins worked at Nashville, 12 miles south of Placerville, in the latter part of 1850 or earlier part of 1851.

The magnitude of the operations on the mother lode gold-belt since the earliest days of mining in California, are best shown by the fact that over the whole length of the lode, a distance of over 100 miles, there is an almost continuous series of mines, comprising more than 500 patented claims, and almost as many unpatented ones.

The lode follows in a general way the north-west and south-east trend of the mountains, the veins conforming usually to the same dip as the enclosing stratified rocks, viz., 40 to 75 degrees. There is, without doubt, no such series of gold-bearing veins as the mother lode to be found elsewhere in the world. While the number of patented mines already exceeds 500, mining here is yet in its infancy. With more careful exploitation, and better means of saving the gold, many more mines can be worked. J. W.

GOLD-FIELDS OF AUSTRALASIA.

By OBERBERGRATH KARL SCHMEISSER, *assisted by* DR. KARL VOGELSANG. *Die Goldfelder Australasiens, pages ix. and* 165, *with* 25 *illustrations*, 13 *maps and plates and numerous tables. Berlin*, 1897, *Dietrich Reimer.*

The first 30 pages are devoted to a brief geographical and physiographical description of Australia, Tasmania and New Zealand, followed by general remarks on their history and economical development.

Then follows (pages 31-36) a short geological description.

Australia (Plate II., geological map, 1/12,000,000 from the official maps of the colonies, revised by Mr. C. L. Wilkinson, geologist of New South Wales) is largely built up of members of the Archæan formations (crystalline schists, gneisses and phyllites, with granite, syenite, diorite, etc.), which, especially the granite, constitute the foundation, and are particularly prominent in the west of the continent. Mr. H. P. Woodward distinguishes in Western Australia five Archæan zones:—(1) A western band of slates and quartzites with granite-intrusions; (2) gneiss and mica schists with granite and felsite-outbreaks, extending from the south coast to Lyons River; (3) main granite zone, about 100 miles from the west coast and as many broad, from the south coast to Murchison River; (4) first auriferous zone, composed of mica and talcose schists, with amphibolites, granites and diorites, about 20 miles broad, extending from the south coast *via* Ravensthorpe, Parker, Southern Cross, Golden Valley, Mounts Jackson, Kenneth, Magnet and Lake Austin to Cue in the Murchison district; (5) second granite zone, about as broad as the first, from the south coast up to Fortescue River. To the east of zone 5 appears a second auriferous zone of the same nature as the first, the eastern limit of which is still unknown, and which extends from Dundas Mountains in the south, *via* Wagemulla, Coolgardie, Three Pinnacles, Ullaring and Lake Carey to Marble Bar and Pilbarra on the north-western coast. The Archæan rocks and old eruptives are also prominent in the central islands (MacDonnel Mountains), and constitute the heart of the eastern chains from Victoria to Queensland (Cape York).

The Palæozoic formations are also widespread: Lower Silurian (? Cambrian) is chiefly developed in western Victoria; Upper Silurian in the east of Victoria and in a large part of New South Wales and South Australia. Devonian is conspicuous in New South Wales, and constitutes in the Kimberley district of Western Australia the Carr Boyd and Albert Edward Mountains. Carboniferous is chiefly developed in New South Wales and Queensland; in Western Australia it appears on the Irvine and Collie rivers, as also in the Kimberley district: valuable coal-beds exist in the three colonies.

Of the Mesozoic, Triassic is represented in New South Wales by the Hawkesbury Sandstone; Oolitic limestones and ferruginous clays with Jurassic fossils are found in the Victoria district of Western Australia, while the Cretaceous appears in Western Australia, in the west of Queensland, as well as in the so-called Desert Sandstone of the central regions.

Tertiary sediments are represented in all the colonies, often interrupted by basalts, andesites and other eruptives. Diluvium and alluvium are widespread in the plains of the interior as in the water-courses of the coasts.

Tasmania (Plate III., geological map, 1/100,000, after Messrs. Gould, Johnston and Sprent) is, at the base, a continuation of the Silurian formations of eastern Australia, interrupted by extensive granite-bosses. The Carboniferous, alternating with diabase-sheets, overlies the Silurian, while Tertiary sediments and basalts are represented in the north and south of the island.

New Zealand (Plate IV., geological map, 1/3,200,000, of Sir James Hector, 1885) has a mountainous backbone of crystalline schists, granite, and Palæozoic sediments. To the west the chain falls abruptly, while to the east its flanks are covered by Mesozoic strata. In the south-east, the highland of Otago is made up of Archæan and Silurian rocks, and in its valleys, as well as east and west of the main chain, thick Tertiary gravels are conspicuous. The coal-seams of Reefton and Brunnerton and the Eocene lignite of Oamaru are of great economical importance. A special volcanic feature in the geology of the North Island, to the west and north-west, is due to the repeated eruptions of trachytes and andesites during and since Tertiary times. The volcano Tongariro (7,515 feet) is still active, while further north, in the region of the hot-lakes, mud-eruptions, geyser-phenomena, and solfataras—to say nothing of the Tarawera catastrophe in 1886—also testify to the continuance of volcanic energy.

Pages 36 to 109 of Dr. Schmeisser's report describe the distribution and mode of occurrence of gold in Australasia. The names of the principal gold-fields are printed boldly in red on the maps above-mentioned, so that their geographical distribution is seen at a glance.

Australia.—In Queensland, there are the Gympie, Charters Towers, Crocodile, Etheridge and Croydon gold-fields, with others of minor importance, such as Ravenswood, Palmer, Hodgkinson, etc. In New South Wales, gold has been discovered and worked in so many localities that only the most prominent are mentioned. They are, in the north, the New England, Clarence and Richmond, Peel and Uralla, and Hunter and Mackay districts; in the west, the Mudge, Tambaroora and Turon, Bathurst, Lachlan, Cobar and Albert districts; in the south, the Tamut and Adelong, and the southern districts. Victoria numbers seven gold-fields, to wit, Bendigo, Castlemaine, Maryborough, Ballarat, Ararat, Beechworth, and Gippsland. South Australia has no extensive gold-fields, and only the "finds" of Teetulpa, Mannahill, Barossa, Mount Pleasant, Gumaracha, Hahndorf, Echunga, Jupiter Creek, and others in the southern territory, and that of Port Darwin in the northern territory are mentioned. In Western Australia, twelve gold-fields have, so far, been proclaimed:—Dundas, Coolgardie, East Cool-

gardie, North Coolgardie, Yilgarn, Yalgoo, Murchison, East Murchison, Ashburton, Pilbarra, West Pilbarra, and Kimberley. Dr. Schmeisser gives the longitude, latitude, extent, and chief townships of most of the above continental gold-fields.

Tasmania has three gold districts: (1) North Coast, with the Tamar field and the Lefroy, Pipers River, Back Creek, Lisle, Denison, and Golconda finds; (2) North-eastern, with the Mangana and Mathinna fields, and the Waterhouse, Gladstone, Mount Horror, Branxholm, Mount Victoria, and Scamander finds; (3) West Coast, with the finds of Piemans and White River, Port Macquarie, King River, and Mount Lyell, and those of the streams that run into Port Davey.

New Zealand also numbers three auriferous districts: (1) Hauraki, on the North Island, comprising the Coromandel peninsula and the land to the south as far as Waiorongomai; (2) West Coast of South Island, from Cape Farewell to the Wanganui River, with the Reefton and Lyell lodes, and the auriferous gravels of Collingwood, Westport, Kumara, Hokitika and Ross; (3) Otago in the south-west of South Island, with various Primary and Secondary deposits.

After this brief geographical review, Dr. Schmeisser considers the occurrence of gold from a purely geological standpoint, grouping the repositories—irrespective of locality—according to the geological age of the formations in which they are found. In Australasia, gold exists in all the geological formations but, with few exceptions, it can only be mined profitably in the Archæan, the Primary, and the Tertiary. Its mode of occurrence is very varied; disseminated in igneous rocks, in lodes, in beds, and in alluvia of different ages; but by far the most frequent mode is that of lodes or veins, either fissure or bedded, contact-lodes being rare.* An interesting table gives a summary or synopsis of this geological classification and mode of occurrence.

ARCHÆAN GROUP.—Auriferous Veins in Crystalline Schists.—They occur frequently in chloritic schists, amphibolites, talcose and sericite-schists in many gold-fields of Western Australia, South Australia, New South Wales, and Queensland, chiefly as bedded veins, but also as fissure-veins. As almost all pre-Carboniferous rocks have a mean north to south trend, the bedded veins usually partake of the same. This is also, generally speaking, the case with the veins and dykes of igneous rocks (diorite, diabase, felsite and porphyry).

Western Australia.—The country-rock of a large number of auriferous lodes is called "diorite;" but although there are some true diorites in the Murchison district, the microscopic examination of many fresh specimens proves the majority to be amphibolites. As they form massive beds in the midst of the crystalline schists, they might genetically be classed with these; it is, however, by no means improbable that they are metamorphosed diabase-dykes, and the question as to their origin must, for the present, remain open. Mica-schists, phillites, and talcose schists also occur as country-rock of gold-veins in Western Australia.

The veins strike chiefly north-north-west to south-south-east, or north to south, or north-north-east to south-south-west, with westerly dip. Locally, they constitute groups or trains. There are two kinds:—(*a*) Simple quartz-veins, the only essential gangue of which is quartz; and (*b*) compound or complex veins locally termed "lode formation," the filling of which consists of more or less decomposed country-rock, intersected by numerous quartz-veinlets or stringers. The quartz-veins proper cross "country" in all directions, but chiefly north and south, with slight variation to east or to west. They vary greatly in thickness, from ½ inch to 40 inches, attaining sometimes 30 to 80 feet; and in each single vein the thickness varies frequently both on strike and on dip; the walls are generally well defined.

* We purposely avoid the use of the new-fangled term *reef*, which is as inappropriate as it was needless.

Some appear as lenticular lodes as, for instance, in the Edjudina group (North Coolgardie), where each vein consists of a row or train of quartz-lenses, more or less separated from one another. The quartz of these simple veins is white, grey, brown, yellowish, greenish, or blackish, and is often cellular or drusy. The compound veins vary in thickness from 3 to 70 feet or more, and this dimension is very changeable in each case. With few exceptions, they have, as yet, only been explored in the upper or decomposed zone, and therefore are filled, partly with a red, brown, or yellow ferruginous clayey stone, partly with white, yellowish, or reddish kaolin. In the Kalgoorlie field, this filling is traversed, usually from east to west, by white, grey, brown, greenish, or black quartz-stringers of varying thickness; the greater their number and the more cellular or spongy the quartz, the richer the lode as a rule. In the majority of cases, only the foot-wall of these lodes is defined; on the hanging-wall, the filling merges gradually into the "country;" slickensides are frequent on the foot-wall and in the lode itself.

Whereas the simple quartz-veins occur in all the Western Australian districts, the compound veins, so far as yet ascertained, are confined chiefly to the Kalgoorlie, Broad Arrow, Bardock and Bulong groups of East Coolgardie. However, in the Menzies, Yalgoo, Mount Magnet, and other groups, some more or less typical veins of this class have been discovered. The best mines of Kalgoorlie (Great Boulder, Lake View, Ivanhoe and Hannan's Brownhill) are on compound veins.

The quartz-veins proper are, for the most part, easily traced at the surface by conspicuous outcrops or the loose *débris* of the same; but the compound veins only offer, at best, some indication in the iron-stained ground The lodes striking east-and-west are, as a rule, inferior to the north-and-south lodes in extent and value.

Gold is found, not only in the quartz-veins proper and in the stringers of the compound veins, but also in the filling mass of the latter. In the first, it may average from 1 to 2 ounces per ton; in the stringers, from 1 to 4 ounces or more; but in the mass or filling, it ranges from mere traces up to 1 ounce at most. A few crushings have been reported with 3, 5, and even 15 ounces of gold to the ton. Usually, the gold is in a very fine state of division, and cannot be seen. Visible gold is, however, often met with—in the compound veins, as a fine powder, or in specks or spangles, or as a soft mosslike or spongy deposit which may be wiped off with the finger, or in thin plates or thick, irregular nuggety bits. In the quartz-veins proper, with yellow, brown, or grey quartz, the gold is usually finely disseminated throughout, while in milk-white quartz it commonly appears in spangles or irregular nuggets in the fissures; white quartz with glassy lustre is very poor. As a rule, the gold is concentrated in shoots, which are sometimes extraordinarily rich, though within a given shoot, the gold contents may vary considerably; outside the shoots, a lode may be entirely unproductive. In many cases also a concentration of gold has taken place in isolated patches or pockets near the surface, while at even a very moderate depth the lode rapidly impoverished, as in the case of the Londonderry and Edjudina mines. The silver content of the gold is inconsiderable.

The associated minerals met with in the lower, undecomposed zones of the lodes are iron and arsenical pyrites; here and there a little galena, and rarely chalcopyrite; in the upper parts, the products of decomposition of these minerals are found. Recently, tellurides of gold (sylvanite, calaverite, krenerite) have been met with in the compound veins of Kalgoorlie, Broad Arrow, Bardock, and Bulong, below the gossany or decomposed zone, *i.e.*, at a depth of 150 to 250 feet. Tellurides of silver (petzite, hessite, etc.) invariably accompany them, and they are usually associated with pyrites.

The depth of the decomposed zone varies considerably. For instance, in the Cue district, it averages 60 to 100 feet; and in Menzies and Kalgoorlie, 130 to 180 feet. The "country" is usually decomposed to the same depth as the veins. Cross-veins, either auriferous or of igneous rock and faults, with their disturbing influence, are met with, but are not frequent.

As to the genesis of the Western Australian lodes:—As a rule, the simple quartz-veins, as well as the compound veins, may be regarded as mineralized fissures, the opening of which gave rise, in most instances, to a displacement of the sundered rock-masses; the only difference is that, in compound veins, larger parts of the rock have been shattered and crushed and now constitute the filling or "formation." Between the two extreme lode-types, other intermediate ones may be studied in all stages of development; they are, as a rule, much poorer than the typical compound veins, which fact does not prevent the Western Australian miner from applying to them the term "lode formation" in order to enhance their value!

As to the question of value in depth, below the decomposed zone, the Ivanhoe, Great Boulder, Boulder Perseverance, and Lake View lodes may be quoted as instances of compound veins maintaining their value in the undecomposed or pyritic depths; on the other hand, several compound veins have greatly pinched and impoverished, or even completely wedged out, on attaining the undecomposed level. Finally, Dr. Schmeisser cannot admit, for the present, the recently propounded theory, that the telluride lodes are the outcome of igneous or eruptive action.

New South Wales.—The conditions of the auriferous lodes in the crystalline schists of this colony are similar to those of the simple quartz-veins of Western Australia and call for no further notice.

Some repositories of Peak Hill, in the Mudgee district, may be considered as compound veins: they occur in talcose schist, without defined walls, one of them, for instance, being made up of 7 feet of ferruginous quartz and quartzose talc-schist, 10 feet of talc-schist, 7 feet of quartzose talc-schist, 23½ feet of talc-schist and 3 feet of the same with ferruginous quartz-stringers; several samples of this lode yielded 1¼ to 10¼ ounces of gold per ton, which, as a rule, is not visible. In the Caloola field, Bathurst district, gold occurs, not only in the quartz-lenses between the layers of the mica-schist, but also in the schist itself close to the quartz; in some cases barren quartz-lenses have been found between auriferous layers of schist.

Auriferous Lodes in Granite.—A large number of gold-veins in many localities occur in granite which is, in the great majority of cases, of Archæan origin. Although younger auriferous granites may exist, their age is so difficult to determine that they will be considered in this place with the older ones. The lodes of the Croydon and Etheridge fields in Queensland, those of Wagonga in New South Wales, and those of Ararat in Victoria, occur in normal granite, while the lodes of Charters Towers, Ravenswood, and other fields of Queensland, and those of Armidale (in part), Yalgogrin, Wyalong, Gundagai, Tumut, Adelong, Braidwood, Garangulah, Majors Creek, and others of New South Wales are found in hornblende-granite.

Queensland.—In the Croydon field, both hard, solid granite and highly decomposed granite, with graphite, occur side by side, but, so far, auriferous quartz-veins have only been discovered in the decomposed rock. They mostly strike north-north-west and dip to the north-east, have great length, a width of 2½ to 6 feet, and are, in general, tolerably regular. The gold occurs chiefly in a free

state, largely alloyed with silver, so that it is not worth more than 47s. per ounce; in depth, iron and arsenical pyrites, and sometimes galena, appear. The most important lodes are the Iguana, Golden Gate, and Queen.

In the Etheridge field, the lodes strike east-and-west, and dip to the north, the decomposed zone is 65 to 80 feet deep, and below it the auriferous quartz contains iron and arsenical pyrites, and a little zinc-blende and galena. In the now shut-down Cumberland mine, the lode impoverished at the 600 feet level, and appeared to wedge out at the 850 feet level. The principal mines are the Nil Desperandum and the Queenslander; in the former, the lode has been proved over a length of 1,700 feet, and is said to average 1½ to 2 ounces of gold per ton, but the crude gold is not worth more than 57s. per ounce.

Charters Towers.—The hornblende-granite of this field is intersected by numerous auriferous veins and others of felsite and diorite, the first of which strike in very different directions, though their dip is chiefly to north. The width of the gold-veins also varies considerably, but averages about 3 feet, and many of them show no outcrop. The gangue is quartz and decomposed "country;" near the surface the visible gold is accompanied by limonite; in depth it is much finer, and occurs with much iron and arsenical pyrites, and but very little galena and zinc-blende. The principal mines are on the Brilliant lode, the gold content of which varies considerably: 1 to 2 ounces per ton were formerly frequent, but the deepest levels (2,000 to 2,300 feet) only yield ⅔ ounce.

Besides Charters Towers, the only important field of Queensland in hornblende-granite is that of Ravenswood, where the gold content varies from 186 to 354 grains per ton. Accessory minerals are chalcopyrite, arsenical pyrites, and zinc-blende.

New South Wales.—Wagonga field.—In Mount Dromedary, a quartz-vein of 1 to 12 inches strikes east-north-east through decomposed granite. The auriferous quartz carries much iron pyrites, which is decomposed as far down as the granite. Outside the vein, the decomposed rock is often sufficiently auriferous to be worth milling.

In New South Wales, the gold-fields already-mentioned offer, in general, great similarity, and in most of them the hornblende-granite is traversed in different directions by many auriferous lodes of the lenticular type, which is particularly marked at Garangulah. The width of the lodes varies from a few inches to 7 feet; the filling consists of auriferous quartz with limonite and sometimes oxides of manganese and copper, malachite, chessylite, galena, cerussite and wulfenite in the upper levels, and of auriferous quartz with iron and arsenical pyrites, chalcopyrite, zinc-blende and galena below the decomposed zone. The gold is usually freely disseminated and in shoots, sometimes coarse near the outcrop, and varies much in quantity. Some lodes have proved profitable at considerable depths, while others, rich at the surface, have impoverished or disappeared at the lower levels. In some lodes of the Wyalong field, nodules occur, composed inwardly of arsenical pyrites, which passes, towards the outside, into limonite with minute specks of visible gold. Small yet visible spangles of gold are also met with in the granite out of the lodes.

Auriferous Lodes in Quartz-diorite.—In the Murchison field (Western Australia) to the north and south of Cue, a wide region, is taken up by quartz-diorite limited to the east and west by crystalline schists; it is much decomposed to a depth of 90 to 110 feet, forming a friable kaolinic mass, usually white, but often brownish; but below these depths the rock is comparatively fresh. It is traversed in different directions by a number of lodes, averaging 3 to 4 feet in width, composed of irregular lenticular quartz-bodies, between which and the usually well-

defined walls a selvage of quartzose kaolin often appears, due to the decomposition of the diorite. The gold occurs chiefly in the quartz, subordinately in the kaolin, generally in a fine state of division, yet sometimes in visible spangles and coarser bits. The gold content, as reported, varies between 1 ounce and 2¼ ounces per ton, but as a concentration of the precious metal near the outcrop almost invariably obtains, it is questionable whether the said content will hold out in depth. Besides this, some lodes are very irregular, both in strike and in dip.

AURIFEROUS LODES IN QUARTZ-PORPHYRY.—North-east of Croydon (Queensland) auriferous quartz-veins occur in felsite, and in the Golden Valley, 18 miles away, in quartz-porphyry. The veins are thin and the gold they bear is finer than that of the granite-lodes, being worth 65s. per ounce as against 45s.

AURIFEROUS LODES IN PORPHYRITE.—This rock is intersected by many gold-veins in the Black Snake field (Queensland). The gangue is porphyritic, and the ores consist of a mixture of iron and arsenical pyrites, galena, zinc-blende, chalcopyrite, and quartz, with about 1 ounce of gold to the ton. In the porphyrite of the Cargo field (New South Wales), lodes also occur with fine bloodstone in which auriferous pyrite is embedded.

AURIFEROUS LODES IN SYENITE.—In Brown's Creek, Bathurst (New South Wales), syenite is traversed at a high angle by several powerful and parallel lodes of ordinary quartz.

SILURIAN GROUP.—All the gold-fields of Victoria belong to this formation, and also important repositories in the Orange, Hargreaves, Hillend, Wellington, Lyndhurst, and other fields of New South Wales, several of the north-east Tasmanian fields and those of Otago, in New Zealand.

AURIFEROUS SEDIMENTARY ROCKS.—In Mount Drysdale (New South Wales), siliceous slates, sandstones, and conglomerates are said to occur in which gold is finely disseminated and seldom visible, or is concentrated in shoots yielding from ½ ounce to 30 ounces per ton. Similar auriferous slates are reported from Mount Allen and some mines near Cobar.

AURIFEROUS LODES.—Victoria is the most important region of Australasia for Silurian gold-veins, chiefly bedded veins. In the Lower Silurian of Ballarat, their gangue is mainly quartz, with sometimes argillaceous, sandy stone, and pieces of more or less decomposed "country." Near the outcrop, the quartz is crumbly or honeycombed, with ferruginous masses, resulting from decomposed pyrite, in which free gold is finely disseminated. In the fresh zone, the gold is, in part, finely disseminated, in part coarse and visible, with iron and arsenical pyrites in large masses here and there. The so-called "indicator-lodes" of this field are specially interesting: the "indicators" are thin beds (½ to 2 inches) of highly bituminous shale, full of pyrite, parallel to the planes of stratification of the enclosing slates, and, like these, dipping nearly vertically. Their dark colour contrasts with that of the light-grey slates, and they can be traced for miles. A great number of quartz-veins cross the slates in every direction, others constitute bedded veins; these latter are poor, but the veins which cut the bedding-planes more or less at right angles average 10 to 15 inches of white quartz, with pyrite, galena and blende, and contain very rich patches of nuggety gold at the line of intersection with the "indicators," although they are, in most cases, quite poor, not more than a foot from the plane of intersection. This concentration of the gold is probably due to the reducing action of the bitumen of the shale on the mineral solutions.

The Cohens lode, near Walhalla, Gippsland (Victoria), deserves special notice for its size, regularity, and richness. It is a compound lode of what appears to be an eruptive gangue, intersected by numerous quartz-stringers, and is worked to a depth of 800 feet. Here, as elsewhere in the colony, the Upper Silurian rocks are

traversed by powerful diorite-dykes, which appear to favourably influence the gold content of the lodes. Dr. Murray asserts that in Victoria, as a rule, the Lower Silurian lodes are more numerous, stronger, but poorer, than the Upper Silurian. In 1890, the average of the millings was: Beechworth 13½ dwts. and Gippsland 15 dwts. per ton, against Ballarat 7½ dwts., and Bendigo 9 dwts. per ton.

The folding or corrugation of the Lower Silurian slates and sandstones of Bendigo has led to the formation of anticlinal and synclinal deposits of auriferous quartz, resulting most probably from the filling up of spaces opened during the plication. These "saddle-lodes" are so well known after the able descriptions of Messrs. Dunn and Rickard that a repetition is unnecessary. Eleven parallel anticlines, with auriferous saddle-lodes, have been discovered, but only three are worked extensively: the New Chum, on a length of 13½ miles, and to a maximum depth of 2,964 feet; the Garden Gulley, 6¾ miles and 2,128 feet; and the Hustlers, 5 miles and 1,850 feet. In some cases, the saddle-lodes are superposed at short intervals, in others they are few and far between. Thus, within a depth of 2,400 feet the shafts of the New Chum and Victoria mines have traversed 30 saddles, while in the 180 Mine only 5 were found. Mining is chiefly confined to the anticlines, though similar gold-bearing quartz-masses have been found in the synclines or inverted saddles; they appear, however, to be less numerous and poorer than the saddles. The gangue is usually white quartz, in which fragments of "country" frequently occur. The gold is very irregularly disseminated, and not all the saddles can be mined to profit. Accessory minerals are iron and arsenical pyrites, and occasionally zinc-blende and galena.

Besides these important repositories, the Silurian formation of Bendigo contains fissure-veins, network quartz-deposits, and ore-bodies, which have often proved rich in gold.

In the Hargraves field of New South Wales several saddle-lodes occur, similar to those of Bendigo, though of minor importance. The discovery of a saddle-lode near Hillend has also been reported.

Near Nerrigundah, north-west of Mount Dromedary, lenticular quartz-lodes have been worked, but although some of them proved very rich at the surface, they have all given out in depth. In the Bywong field, a great number of parallel thin quartz-veins follow the planes of stratification of the Silurian slates.

North-eastern Tasmania.—They do not differ essentially from those of the Australian continent. The most important mine is the Tasmania, near Beaconsfield, with lodes from 1 foot to 16 feet wide, and average gold content of 1¼ ounces per ton, which have been opened up to a depth of 700 feet. But the deepest mine is the Golden Gate, in the Mathinna field, where four strong quartz veins yield on an average 1½ ounces per ton, with paying ore at a depth of 1,000 feet.

New Zealand.—Otago District.—A zone, 70 miles broad, of mica-schists or phyllites, considered as of Lower Silurian age, contains many irregular, more or less lenticular, quartz-beds. Not only many of these bedded veins, but also a number of true fissure cross-veins, have proved auriferous. The gold content varies considerably, but averages less than 12 dwts. per ton, though very rich ore has been found in places. Iron pyrites is common, and antimonite, zinc-blende, and galena sometimes occur. In the south-west of Otago, on Wilson River and Preservation Inlet, Lower Silurian quartzites, sandstones and bituminous or graphitic slates are to the fore. Where these rocks are in contact with the granite they are transformed into quartzose mica-schist, which is more or less auriferous.

Gold in Igneous Rocks.—*New South Wales.*—On the left bank of the Bellubula river, between Mandurama, Ponds Creek and Marangulla Creek, and also further

north, in the Frenchman and Cornishman fields, zones of altered diorite occur in which pyrite and gold are disseminated. They strike north-east to south-west, dip 20 to 30 degrees to the north-west, vary greatly in width, and are composed of a mouldy, argillaceous or siliceous, reddish or yellowish-brown mass, in which gold and silver are so finely distributed as to be nowhere visible. The gold content is also very irregular, so that parts worth 1 to 2 ounces per ton alternate with barren parts, and the average must be very small. Here and there the precious metals are concentrated in pockets with iron and arsenical pyrites. The country is traversed by dykes or veins of diorite of more recent date, which have given rise to dislocations in the vicinity of which the auriferous zones have been enriched.

Auriferous fissure-veins repeatedly occur in the diorite-masses of Silurian age; for instance, in the Mitchell's Creek mine, near Daviesville, Mudge district. This lode strikes north-and-south for a considerable length, dips 45 degrees east, and has been worked to depths of 500 to 700 feet on the dip, proving very regular, with an average width of 2 feet. The walls are well defined, and the filling consists of alternate bands of quartz and pyrite, with an average gold content of 15 dwts. per ton. Fragments of the diorite also occur in the lode-mass.

In the Pambula gold-field, Auckland, rhyolite and quartz-porphyry occur together. The rhyolite is traversed in different directions (chiefly north and south) by peculiar veins, composed of irregular, lenticular portions of rhyolite, separated by a soft argillaceous mass. The hanging-wall is usually well defined, with an occasional quartz-leader, while on the foot-wall the lode-stuff gradually blends with the "country." The quartz-leaders contain little or no gold, which is concentrated in fissures of the crushed rhyolite on the foot-wall side, and especially in the intermediate clayey mass. The more the lode-stuff is broken up, and the wider the vein, the richer it proves, apart from the shoots in which, here and there, the gold is concentrated. Pyrites accompanies the ore in depth. The north-and-south lodes are richer than those of other strikes. On the summit of Mount Gahan, the lode yielded 32 dwts. to the ton, and in Pipe-clay Gully ore has been raised with 32 ounces.

In the Wentworth gold-fields and the Aladdin's Lamp mines, near Lucknow, Bathurst, pyroxene-andesite (locally termed diorite) occurs in contact with serpentine. The contact-zone is characterized by a row of calcite and dolomite-bodies, 3 to 4 feet thick, and up to 100 feet long, in which, as also in the neighbouring parts of the hanging-wall serpentine, gold, iron, and arsenical pyrites and native antimony occur. The arsenical pyrites is generally rich in gold, the iron pyrites poor. The ore averages 3½ ounces of gold per ton.

DEVONIAN GROUP.—In the Nundle gold-field, Parry (New South Wales), auriferous quartz-veins occur in Devonian slates, conglomerates, and sandstones, and in diorite and serpentine; several of them pass from the sedimentary rocks into the igneous. These veins vary in thickness from ½ to 12 inches, and carry from ½ to 3 ounces of gold per ton, which is very irregularly distributed in pockets and shoots, and concentrated chiefly where the veins cross clay-slate beds. Similar lodes are found in the Devonian slates and sandstones of Nana Creek, Fitzroy (New South Wales), and of the Mount Poole gold-field.

According to Dr. Wolff, the diorite dykes which traverse the Devonian strata of Queensland, have the same enriching influence on the auriferous lodes as the diorites of Victoria, and the like applies to New South Wales.

CARBONIFEROUS GROUP.—Gold has been found disseminated in the Carboniferous sandstone of Springs Creek, 12 miles from Clermont, and in the conglomerate of Tallawang, Philip (New South Wales), but at Springs Creek mining proved unprofitable. Gold-finds have further been made in the argillaceous

slates and conglomerates of Peak Downs (Queensland), the Coal-measures of Stoney's Flat on the Shoalhaven River, and the conglomerate of Wingello (New South Wales, near Hobart (Tasmania), and also in New Zealand. Auriferous veins occur in Carboniferous deposits in the Gympie, Hodgkinson, Palmer and Croydon (Queensland) gold-fields (Queensland), in those of Swamp Oak, Nanga and Queanbeyan (New South Wales), and in the Reefton and Lyell fields of New Zealand.

The so-called Gympie formation (greywackes, sandstones, conglomerates, slates and limestones, alternating with diabase sheets) is traversed by a great number of gold-bearing lodes, which can only be mined to profit where they cross the slates. Four zones of these latter have, so far, been explored, the upper one of which (Phœnix or Monkland slates) is about 2,000 feet thick. From the lodes of this zone the bulk of the Gympie gold is derived; the other three zones are less important. The lodes are chiefly composed of a whitish, milky quartz, with calcite here and there, in which visible free gold is irregularly distributed; very rich pockets are often found in disturbed parts of the veins, which will assay as high as 70 ounces of gold to the ton. Pyrite and galena also occur, but are poor in gold. The Monkland shaft is 1,600 feet deep.

The Crocodile field (Queensland) has but one auriferous repository of importance, that of the celebrated Mount Morgan. It is a gold-bearing mass of bluish grey quartz, siliceous hæmatite, manganiferous ironstone, white spongy or pumiceous siliceous sinter, ochre and kaolin. From a depth of about 300 feet downwards, this iron-impregnated gossanly mass, or iron cap, passes gradually into pyritic ore, i.e., into the pyritiferous quartzite on which it rests. The gold is very finely disseminated throughout, and rarely visible in spangles; the average content has gradually increased in depth, from 5 ounces 16 dwts. 16 grains per ton in 1887 to 1 ounce 11 dwts. 23 grains in 1896. The annual tonnage is, at present, 95,000 with 147,000 ounces of gold. As to the genesis of this deposit (which is traversed by several diorite, rhyolite and felsite veins), Dr. Schmeisser sides with Mr. T. A. Rickard, who considers it to be pyritiferous quartzite shattered and crushed by the intrusion of dykes, and then altered by the percolation of mineral solutions, the gold having being derived from the pyrites or, possibly, from the neighbouring auriferous sandstone.

The Carboniferous slates and sandstones of the New South Wales fields, above named, are traversed by many quartz-veins, which are only gold-bearing in the vicinity of diorite-dykes. In the Storm King mine, the ore averages 1 to 2 ounces of gold per ton, and assays sometimes over 16 ounces.

In the Reefton field of New Zealand, bedded quartz-veins occur in grey talcose-slate and sandstones of Carboniferous age. The gold is chiefly in a fine state of division, averaging ½ ounce to the ton, and some veins carry considerable quantities of antimonite. Auriferous pyrite is frequent, galena rare. A few years back, several lodes pinched or wedged-out in depth, but one of them (in the Keep-it-dark mine) has since been followed down to a depth of 1,100 feet, where it still is now 16 feet wide, with ½ ounce of gold per ton. The mines of this field have the advantage of good coal-seams, which are worked side by side with the gold-veins. Similar conditions obtain in the Lyell field, about 25 miles north of Reefton.

TRIASSIC.—Traces of gold are reported to have been discovered in the sandstone of the Hawkesbury beds at Govet's Leap and Togo Creek, north of Sydney, in the conglomerate of the Mittagong range and in the vicinity of Goulburn.

JURASSIC.—Auriferous rocks of this age occur near Fitzroy Downs and Peak Downs, Queensland, and some Mesozoic carboniferous shales of Victoria carry gold associated with pyrite.

CRETACEOUS.—In New South Wales, an ancient river-bed, filled with coarse gravel, which underlies the Cretaceous sandstone near Mount Browne, has been profitably mined for gold to a depth of 250 feet, but had to be abandoned on account of the water. Similar repositories have been found near Tibooburra and between Kayrunnera and Tarella. The Desert Sandstone of Queensland is also gold-bearing in places.

The so-called cements of Western Australia, which Dr. Schmeisser considers possibly of Mesozoic age, and which occur in the Kanowna, 25 Miles, East Murchison, and other districts, are described as auriferous sandstones, conglomerates, or breccias, composed of rounded or angular fragments of quartz embedded in a soft, clayey or talcose mineral of different colours. The thickness of the beds varies between 10 inches and 20 feet. They are probably derived from the weathering and decomposition of quartz-vein outcrops.

TERTIARY.—In the wider valleys of New South Wales, Victoria, South Australia, Tasmania, and New Zealand, and to some extent also in Queensland, ancient river-beds of Tertiary age are met with, the gravels of which, where derived from Palæozoic formations, have proved to be more or less gold-bearing. They are the so-called "deep leads" so often described, and which were mined long before the primary gold-repositories. These gravel-beds alternate repeatedly with sheets of basalt, and vary greatly in thickness from 3 to 350 feet, though the gold-bearing parts only range from 1 to 20 feet. Near the mouth of the Richmond river (New South Wales), a basalt cliff rises vertically out of the sea, and contains, near its base, a bed of basalt-slag or tuff which assays from 2½ to 18 dwts. of gold to the ton.

In the Hauraki gold-field, which embraces the Coromandel Peninsula of North Island (New Zealand), the Tertiary andesite and its congener the propylite are traversed by numerous quartz-veins, which are relatively strong and rich in gold in the propylite, but narrow and poor in the andesite.

Dr. Schmeisser's description of the Thames district does not differ materially from that of Dr. Park (*Papers and Reports relating to Minerals and Mining*, Wellington, 1894), whose coloured map and sections are reproduced in Plate IX., and as Mr. H. M. Cadell's comprehensive paper on Hauraki, with Dr. Park's map, has recently appeared in the *Transactions*,* we will only give Dr. Schmeisser's opinion as to the future of the field. He states that much depends upon whether the propylite can be proved to be an original rock, for if it is but a decomposed or altered andesite, it will, of course, at a lesser or greater depth, change into andesite in which the lodes pinch out or impoverish.

DILUVIUM AND ALLUVIUM.—Deposits of auriferous sands and gravels have been formed since Tertiary times in a great many of the gold-fields of Queensland, New South Wales, Victoria, Tasmania, and New Zealand, and have been worked to advantage. In Western Australia, the term "eluvial" for comparatively recent deposits is more appropriate, as they were for the most part evidently formed more or less *in situ*, that is near the outcrops of the lodes. The largest eluvial Western Australian nugget was found in 1890 in the Pilbarra field, and weighed 333 ounces.

For many years, and at different spots along the Australian coast, from Port Macquarie in New South Wales up to Queensland, a black, ferruginous sand, containing gold, platinum and tin, has been obtained at low tide, and is the result of the concentrating action of the surf on the sea-sands. The sounding-lead of H.M.S. *Herald* is reported to have brought up gold nuggets from the bottom of Port

* *Trans. Fed. Inst.*, vol. x., page 389.

Macquarie. Auriferous sands are also met with on the West Coast of New Zealand South Island, as well as on that of the Coromandel peninsula.

Dr. Schmeisser's last chapter treats of gold-winning in Australasia, and is a very summary account of its history, the laws which govern it, and of the mining and milling methods in vogue, which offers nothing particularly new to the readers of the *Transactions*. Having regard to the scarcity of water in the principal Western Australian gold-fields, Dr. Schmeisser is a decided partizan of the Krupp dry-milling process (presumably the Pape-Henneberg centrifugal concentration).

Some interesting data are brought together as to workmen and their wages, engineering and management of mines, cost of production, etc.; while the strictures on the all-pervading promoting, company-mongering, and stock-jobbing —though not by any means new reading—are, unfortunately, as welcome and to the point as ever.

General remarks on the statistics of Australasian gold-production introduce us to eight detailed tables concerning the production of the different colonies in 1894 or 1895, and Plate XIII. gives a graphic summary of the yearly production of each since gold was first mined.

Finally, as to the future of gold-mining in Australasia, Dr. Schmeisser points out that, as several mines of Bendigo and Queensland are raising good ore from depths of 2,000 to 3,000 feet, the opinion—which for some authorities is tantamount to an axiom—viz., that gold-veins impoverish in depth, is certainly untenable as a rule; although, on the other hand, it is undoubtedly borne out in numerous instances. He considers, further, that—apart from the many auriferous repositories already discovered, but which do not pay under existing local conditions, though a change in these might render them profitable—regions, more or less untrodden, still exist in the colonies where gold-bearing ground may be discovered in the future. All of which points to the conclusion that, for a long time to come, Australasia will continue to be a leading gold-producer. F. G.

THE MOROSCO FUSION-PROCESS FOR SULPHIDE-GOLD ORES.

ANON. *The Engineering and Mining Journal* [*New York*], 1896, *vol. lxi., page* 495, *and* 1 *illustration.*

A plant has been erected within the past year in the little mining town of Amador City which may have an important influence on the working of gold-bearing sulphide ores. The subjection of calcined ore to a molten lead bath, and extraction of the precious metals by so doing, is not an idea of recent date. To devise practical machinery for feeding the ore continuously into the lead; to then handle the same in its passage through the molten metal, so as to bring every particle of ore in contact with the lead for a sufficient length of time, to ensure perfect extraction of the precious metals; to discharge the tailings from the apparatus without any loss of lead; and to combine all these points successfully, has required much thought, labour, and capital.

The ore being reduced to 30 or 40 mesh is then roasted to burn off sulphur, etc. The roasted ore, while still at a high temperature, is at once fed into the bath-machine. The introduced ore must be considerably above the melting point of lead (640° Fahr.) in order that there may be no chilling effect upon the lead-bath.

The roasted ore is fed in a steady stream automatically to the bottom of the bath-well, which is a very heavy iron casting, 30 inches in diameter and 6 feet deep. The ore on reaching the bottom of this casting is freed, and at once attempts to rise by its own gravity through the bath of molten lead, of which there is over 5

tons. In this chamber are circular perforated plates, with reversed stir-arms between, and the ore is caught by the first stirrers and segregated, passing through the first plate and on to the second set of stirrers, and so on to the surface of the molten lead, where it is discharged automatically by a rapidly revolving disc, then to a trap-box of running water, which immediately chills the ore, and thence passes on to the concentrator. After the ore has passed through the bath it is said to carry no gold or silver, as the precious metals have become fused with the lead and are left behind in the well, while the ore as discharged into the water-box carries with it about 44 per cent. of lead, which is all recovered on the concentrators, re-melted and refined, and is used again in the bath. About 12 horse-power is required for running the machinery.

It is claimed that gold-bearing sulphides and base ores can be worked by this process for from 12s. to 16s. per ton, and yield over 90 per cent. extraction.

J. W.

ZINC *VERSUS* ELECTRICITY FOR CYANIDE GOLD-PRECIPITATION.

(1) *The Cyanide Process.* *By* JOHN YATES. *Proceedings of the Chemical and Metallurgical Society of South Africa*, 1894-1897, *vol. i., pages* 254 *to* 267.

The year 1895 witnessed the production of over 600,000 ounces of bullion by the cyanide process on the Rand; it is not surprising, therefore, that cyaniding should receive so much attention among those interested in gold-mining.

Two processes are now in use on the Rand for the precipitation of gold from cyanide solutions: first, the zinc process of Messrs. MacArthur and Forrest; and secondly, the electrical process introduced by Messrs. Siemens and Halske. The first-named gentlemen were the first to introduce zinc as a practicable precipitant, and they recommended the use of this metal in a fine thread, or shaving, such as is got by turning down thin discs of zinc in a lathe. Since 1890, when the cyanide process was first used on the Rand, the precipitant was without a rival; until, two years ago, when the Siemens-Halske electrical precipitation-process was introduced at the Worcester gold-mine, sheet lead being the cathode metal on which the gold is deposited as a film. The main feature in the plant for the latter process is the extra size of the extraction-boxes. The Worcester installation, having a capacity of 3,000 tons tailings per month, has four of these boxes, each 20 feet by 8 feet by 4 feet. The iron anodes are $\frac{1}{8}$ inch thick and 7 feet long by 3 feet wide. For the generation of the current, a dynamo requiring 5 horse-power is used.

To prevent short-circuiting, the anodes are covered with canvas, and the strongest cyanide-solution used on the tailings is only 0·1 per cent. The number and capacity of the leaching-vats have to be such as to permit of the tailings remaining longer under these solutions than is the case with ordinary zinc precipitation, where solutions as strong as 0·3 per cent. are used. The clean-up in the electrical process consists in taking the leaden sheets off their frames and replacing them by others; the auriferous sheets are melted down, cast into blocks, and then despatched to a central works for cupellation, the resulting bullion being finer than that yielded from zinc treatment.

A reduced size of box has been adopted in the newer plants, on the Siemens-Halske system, erected at the May Consolidated and Crown Reef mines. The Crown Reef has 4 boxes, 30 feet by 4 feet by 6 feet, each divided into 6 compartments. The labour required by the lead cathodes has been increased by using the lead in strips, instead of sheets as formerly. About 6 Siemens-Halske plants are now at work on the Rand. A plant at the Metropolitan mine, designed for very weak cyanide-

solutions and electrical precipitation, was run alongside of another plant on the zinc system for 11 months, when the electrical process was discarded, and now, cyanide solutions up to 0·4 per cent. are used. Mr. Yates appreciates the value of electric precipitation for slimes treatment, where excessively dilute solutions of cyanide are used: the strongest solution used for this purpose at the Crown Reef plant being 0·008 per cent.

The cost of treatment by each method is shown, per ton of tailings treated, in the following statements, where two plants are assumed, each of 500 tons per day capacity, of good and similar general design; the one plant being arranged for zinc precipitation with 4 days' treatment, and the other for electric precipitation with 6 days' treatment:—

MacArthur-Forrest Process, 500 Tons per Day Plant, Costs per Ton.—

With Zinc Precipitation.	s.	d.
Filling and discharging	0	10·00
Cyanide of potassium, 0·7 lbs. at 1s. 1½d. per lb.	0	9·40
Lime and caustic soda	0	1·80
White labour	0	5·00
Native wages and food	0	1·90
Fuel and power (including haulage)	0	3·00
Zinc	0	0·75
Stores and general charges	0	2·75
Total cost per ton of tailings	2	10·60

With Electric Precipitation.	s.	d.
Filling and discharging	0	10·00
Cyanide of potassium, ¼ lb. at 1s. 1d. per lb.	0	3·40
Lime and caustic soda	0	1·70
White labour	0	5·00
Native wages and food	0	1·90
Fuel and power (including haulage and dynamo, and fractional maintenance and superintendence of generator and engine)	0	4·00
Lead	0	1·10
Iron	0	2·20
Stores and general charges (including cupellation)	0	3·20
Charge due to extra cost of plant (£5,000)	0	1·30
Loss of interest due to long retention of gold in extractor boxes	0	0·38
Total cost per ton of tailings	2	10·18

(2) *Zinc versus Electric Precipitation.* *By* A. von Gernet. *Ibid., pages* 281 *to* 292.

Replying to Mr. Yates' statement, that weak solutions of cyanide do not in practice always show a solvent efficiency equal to stronger ones, Mr. Von Gernet said though they might not always be, yet he thought that it was in general admitted that the solution of the gold depends much more upon mechanical conditions than upon the strength of the solution employed. Even 0·05 per cent. cyanide-solution, in contact with an equal weight of 5 dwt. tailings, contains more than 88 times the amount of potassium cyanide required. Should, under exceptional circumstances, gold take an extremely long time to dissolve in very weak solutions, a stronger solution would be employed. The amount of cyanide consumed depended mainly:—

1.—Upon decomposition during leaching of tailings, due to the chemical composition of the latter,—this increases with the strength of the solution, since more base metal is dissolved by the stronger, and, consequently, more cyanide is consumed.

2.—Upon decomposition during precipitation. This, with electrical precipitation, is equally small for strong and weak solutions; but, with the zinc process, increases with the strength of the solution used.

3.—Upon cyanide-solution lost by leakage, also as moisture in the residues. It is obvious, then, other things being equal, that in a 0·30 per cent. solution a larger amount of actual potassium cyanide has gone to waste than in a 0·05 per cent. solution.

Electric precipitation was not, of course, confined to weak solutions only, but might be used with equal effect on solutions of any strength.

Costs.—The author criticized some of Mr. Yates' comparisons of costs with plants of different dates; but, he accepted the figures given for electric precipitation, with a few alterations as follows:—

500 Tons Per Day Plant, Cost Per Ton with Electric Precipitation.

	s.	d.
Filling	0	10·0
Cyanide	0	3·4
Lime	0	0·5
White labour	0	5·0
Native labour	0	1·9
Fuel and power	0	4·0
Lead	0	1·5
Iron...	0	0·3
Charges due to extra cost of plant ...	0	0·5
Stores and general charges	0	3·2
Total cost per ton	2	6·3

It will be noted that the costs in the above estimate for iron, alkali, and extra cost of plant are lower than those given by Mr. Yates.

Slimes Treatment.—Here Mr. Yates admitted that the electric process was without a rival. The fact that ordinary low-grade slimes could now be profitably treated on a commercial scale was, as yet, hardly generally appreciated. For the first time in the history of gold metallurgy in the Transvaal had it been possible to treat all products of the ore: free gold, concentrates, tailings and slimes; and not only this, but the necessity which now hampers mining companies, of retaining as much pulp as possible in the tailings-vats at the risk of rendering the sands more or less slimy and unleachable, would disappear.

Early in 1897, slimes-plants capable of treating upwards of 50,000 tons monthly will be at work, and he predicted that, within a year's time, a slimes-plant would be considered just as necessary a complement to the mill as a tailings-plant.

J. W.

RELATIVE EFFICIENCIES OF STRONG AND WEAK CYANIDE-SOLUTIONS FOR DISSOLVING GOLD.

By W. A. Caldecott. *Proceedings of the Chemical and Metallurgical Society of South Africa*, 1894-1897, *vol. i., pages* 293 *to* 296.

The relation between the percentage of gold extracted and the strength of cyanide-solution used is a most important one, both from a scientific and practical point of view.

About a year ago, the writer made a series of experiments on a working scale to determine this question, from which it appeared that with little more than 3 days' treatment the same percentage of gold was extracted by a 0·052 per cent. potassium-cyanide solution as by a 4·334 per cent. solution from the tailings of a typical Rand Company. The explanation of the results might be found in a consideration of the conditions required to dissolve gold in cyanide-solutions. He thought that the fact of the efficient percentage strength of cyanide-solutions being limited by the amount of oxygen available had hardly yet been practically realized, and he trusted that his notes might serve to bring that point into greater prominence. J. W.

THE CYANIDE-PROCESS IN THE UNITED STATES.

By GEORGE A. PACKARD. *Transactions of the American Institute of Mining Engineers*, 1896, *vol. xxvi., pages* 709-721.

This paper gives tables showing the character of the ore treated by cyanide at a number of mills in the United States, and details of the treatment. The process had been applied there, on a large scale, only to rather low-grade, highly siliceous ores, containing but a small percentage of base metals, and having their value chiefly in gold.

An instance is quoted in which cyanide competed successfully with the smelters on ore carrying as high as 4 ounces in gold, the ore being one in which the value was easily extracted to a high percentage.

In the Cripple Creek district, where an extraction of 90 per cent. is obtained in from 4 to 6 days, and where the smelting-charges were from 20s. to 28s. per ton, ore running as high as £8 was in 1895 bought by the cyanide-mills. In the case of ores containing from 1 to 10 ounces of silver, in addition to a commercial gold value, the process has been advantageously employed. The Golden Reward Company, in South Dakota, having ores containing 1 to 5 ounces of silver, which was lost in chlorination, now treats such ores by cyanide. At this plant, early in 1895, they were using for chlorination about 35 lbs. of chemicals per ton of ore, while only 2½ lbs. were necessary for treating 1 ton with cyanide.

The cost of cyaniding varies largely with the nature of the ore. There is a number of mills which crush and cyanide ore for less than 8s. 3d. a ton, exclusive of royalty paid to the company owning the patents. The lowest cost reported is 3s. 6d. a ton at the Mercur.

In the United States, nearly 200,000 tons of ore and tailings were treated by cyanide in 1895, producing over £200,000 in bullion-value. J. W.

THE ACTION OF CYANOGEN ON GOLD.

(1) *On the Position that Cyanogen holds in Relation to the Simple Radicals, and its Inability to Combine Directly with Silver or Gold.* *By* WILLIAM SKEY. *Transactions and Proceedings of the New Zealand Institute*, 1896, *vol. xxix., page* 574.

(2) *Further Results Showing that Free Cyanogen does not Dissolve or even Attack Gold.* *By* WILLIAM SKEY. *Transactions and Proceedings of the New Zealand Institute*, 1896, *vol. xxix., page* 576.

The author records the results of a series of careful experiments in which he shows that a solution of cyanogen gas has no solvent action, even upon extremely finely divided gold, provided that the cyanogen is pure, and that it is prevented

from decomposing, and more especially from forming alkaline cyanides, which are wellknown to dissolve gold. From these experiments the writer also infers that whilst cyanogen is at times monatomic like the compound radical carboxyl, it is on certain occasions diatomic like oxygen, and must not be grouped with the haloids.

[Note by the abstractor. - Aurous cyanide is insoluble in water; the above statements of Mr. Skey are of practical importance, seeing that the MacArthur-Forrest patents claim the use of cyanogen as a solvent for gold.] H. L.

THE FRASCH METHOD OF GOLD-EXTRACTION.

L'Exploitation Minière de l'Or au Transvaal. By ALFRED BOUDON. *La Revue Technique*, 1897, *vol. xviii.*, *page* 172, *with diagrams.*

The author describes a new process devised by Mr. Hermann Frasch, and states that it has been employed in several of the Transvaal mines, but omits to give their names. The process is intended for alluvial deposits too poor to be worked in the ordinary way, but is applicable to other porous or permeable deposits of gold and analogous metals, such as silver and platinum. An aqueous solvent of the metal is to be forced or allowed to filter through the deposit, and the solution of gold or other metal thus obtained is drained off or pumped out, and the metal precipitated. The reagents to be employed are chlorine for gold (and platinum) and bromine for gold, alkaline hyposulphites for silver, and potassium cyanide for gold and silver. Numerous diagrams illustrate how the solutions are to be applied to and withdrawn from the metalliferous deposit. The solution of gold thus produced may be treated chemically or electrically. The author concludes by stating that great hopes are based on this new process. H. L.

THE COMBINED PAPE-HENNEBERG AND GOEPNER-DIEHL PROCESSES OF GOLD-EXTRACTION.

Das combinirte Goldextractions-Verfahren Pape-Henneberg und Goepner-Diehl im Vergleich zu anderen Verfahren. By C. BLÖMEKE. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1897, *vol. xlv.*, *pages* 311, 328, *and* 367.

This process consists of a combination of the Pape-Henneberg system of dry dressing combined with the Goepner-Diehl process of cyanidation; it is especially adapted to gold-fields like Western Australia, where water is deficient. The following are the various operations:—

A. *Crushing.*—The ore is dried in a drying furnace, if it be moist when it comes from the mine. A system of gradual reduction is employed, the fine ore being taken out at each stage, and the ore is crushed successively in rock-breakers, rolls, or some other form of mill for medium crushing, and ball mills or rolls for fine crushing. The finest sieve has 25 to 30 holes to the inch. This process of gradual reduction prevents dead-crushing.

B. *Dressing.*—The plant consists of a prismatic or cylindrical vessel, a portion of the walls of which consists of wire-gauze; the interior of the vessel is connected to an exhaust-fan. The ore is allowed to drop in at the top, and under the influence of the lateral air-currents entering through the gauze the finer and lighter particles fall into divisions nearer the centre, the coarser and heavier nearest to the walls, whilst the finest particles are carried off by the air-current

and collected in a receiver provided with a dust-filter, so that all the crushed ore is recovered without any loss. Six grades of crushed ore are thus made, which are usually treated in three divisions.

C. *Extraction by the Goepner-Diehl Method.*—The solvent is a solution of pure potassium cyanide, to which a secret reagent is added; the auriferous solution is separated by means of filter-presses; to the solution excess of cuprous cyanide is added, and then sulphuric acid, which latter precipitates cuprous and aurous cyanide. After the precipitate has settled, the solution is syphoned off, and can be used again after neutralization by caustic soda and the addition of fresh potassium cyanide. The precipitate is re-dissolved in fresh auriferous solution, and re-precipitated by sulphuric acid, whereby a constant enrichment of the precipitate is produced. When sufficiently enriched, the precipitate is separated by means of a filter-press and dissolved in potassium cyanide; gold is precipitated from the solution by electrolysis, cuprous cyanide being reproduced, and being thus capable of being used over again.

Experiments are quoted with Australian ores in lots up to 1 ton, which have given good results as regards extraction of gold. H. L.

THE ENGELHARDT BROMINE GOLD-EXTRACTION PROCESS IN OPERATION, U.S.A.

By D. C. Pret and H. Trachsler. *The Engineering and Mining Journal [New York]*, 1896, *vol. lxii., page* 295, *and* 1 *ink-photo illustration.*

The so-called "refractory ores" of the La Plata Mountains, Colorado, which, when treated by amalgamation, yield an extremely low extraction, are found to vary in character to a great extent. Little development work has, so far, been done in the district; but, during the last year four mines have been opened up and become regular shippers. Their product, principally tellurium-ore, has since been successfully treated at the bromination-works of Messrs. Pret, Trachsler & Company, at La Plata, Colorado, and the mines have produced enough ore to keep this plant in continuous work.

The ores in question are chiefly tellurium-ores similar to those of Cripple Creek. The gold is combined with tellurium as sylvanite and petzite; in some veins as hessite, the greater part of the gold being replaced by silver. Free gold is only found in the more decomposed ore-bodies near the surface, and those mine-owners who erected stamp-mills have had to suspend operations. After a close investigation upon the most suitable treatment of these ores, the authors came to the conclusion that they had to select one of the three known wet processes: Cyanide, chlorination, or bromination.

The cyanide and chlorination-processes, after experiments, were deemed unsuitable, and the bromination-process was adopted for the following reasons:—First, the solvent power of muriatic acid solution of bromine, in the barrel especially, with the addition of soda-ash or any other cheap carbonic-acid producing alkali, or alkaline earth, is greater than that of chlorine-solutions, the action being also more uniform and quicker, and, therefore, the extraction of gold generally higher. Second, owing to the small amount of bromine used per ton of ore, the freight on chemicals is considerably less than the cost of chemicals used in chlorination. Third, the way of applying the bromine in the barrel takes less time, and the charging of the same is less injurious to the operator.

The analysis of an average sample of La Plata ore, taken from a 100 tons lot, gave: - Silica, 80·5 per cent.; iron sesquioxide, 10·0 per cent.; lime, 1·05 per cent.; magnesia, none; alumina, 3·7 per cent.; sulphur, 2·80 per cent.; total, 98·05 per cent. The remainder of 1·95 per cent. is made up by small quantities of copper, arsenic, chromium, titanium and tellurium, which are easily detected in solutions after treatment. The values in silver and gold of different shipments were found to be from 1·25 ounces to 2 ounces in gold and from 0·5 ounce to 1 ounce in silver per ton. The greater part of the gold is found combined with tellurium, and probably as sulphide of gold in the arsenical iron pyrites.

The Bruckner furnace is used, and a perfect dead roast is got in 8 hours. The roasted ore is elevated from the cooling-floor and charged into a lead-lined revolving barrel with water and the necessary amount of chemicals. The strength of solution employed is on an average 0·25 per cent.; but they found that a 0·15 per cent. solution, equal to 1¼ lbs. of bromine per ton of ore, can be used to advantage. The extraction of the gold takes place in 2 to 3 hours.

The leaching from the barrel takes place in 35 to 45 minutes, even on slimy charges containing quantities of flue-dust. The solutions being free of slimes and perfectly clear, do not require any settling; this is considered a great advantage over the use of barrel-chlorination, where the slimes of sulphate of lime, from "bleach" and sulphuric acid, require from 12 to 24 hours' settling. Thus, much time is saved, and the capacity of the works is materially increased by the use of bromine.

The bromide of gold is decomposed by hydrogen sulphide, the small excess of free bromine being first eliminated by a stream of sulphurous acid and compressed air. The elimination of the free bromine and precipitation of the gold take from 15 to 25 minutes per tank of 3,500 gallons of gold solution The precipitate is settled in the tanks for 2 to 3 hours and the supernatant liquor drawn off, running through a Johnson filter-press. At the "clean-up," the precipitate is refined as in barrel-chlorination. The average extraction on ores pulverized to 16 mesh varied from 93 to 96 per cent. J. W.

THE GRAPHITE-DEPOSITS OF NORTHERN MORAVIA.

Die Graphitablagerung bei Mährisch-Altstadt—Goldenstein. By FRANZ KRETSCHMER. *Jahrbuch der k. k. geologischen Reichsanstalt, 1897, vol. xlvii., pages 21 to 56, with a figure in the text and Plate I. (map), Vienna.*

These deposits occur in Archæan crystalline limestones, which are interbedded with amphibolites and schistose muscovite-gneiss. The limestone is granular, varying in colour from grey to greyish-blue and black, by reason of the intermixture with it of graphite-scales. It is seamed by thin bands of dark green serpentine, which is in places decomposed to steatite. Here and there, the whole mass of the limestone is impregnated with serpentine. The limestone forming the floor of the seams is white to light grey in colour, coarse-grained, marmorized, and massive. The limestone forming the roof is finer in grain, darker in colour, and more thinly bedded. The map shows that these graphite-bearing limestones form a mere ring some 300 to 450 feet broad round a central core of gneisses and amphibolites, the latter rocks being repeated outside the ring. The longitudinal section shows that the Sattel graphite-seam forms the two limbs of an anticlinal, while the Baderberg and Vorwerk seams each form one limb of a small synclinal.

The graphite is iron-black, greasy to the touch, has a strong metallic lustre, and occurs in small scales or schistose aggregates of large flakes, and is impregnated with finely divided iron pyrites. Other impurities are white quartz and calcspar, dark limestone, brown iron ore, and strongly kaolinized gneiss. The mineral passes in some places into a hard schistose mass forming a true graphite schist. The average percentage composition, deduced from a long series of chemical analyses, is :—

Carbon	53
Ash	44
Water (loss on ignition)	3
	100

The ash is largely made up of silica and iron oxide, with very little alumina, magnesia, sulphur, etc. This graphite is the richest in carbon of any in Moravia, and most of the pyrites is easily got rid of in the preliminary sorting (in the wet way).

The lowest seam is the Sattel, forming, as before stated, the limbs of an anticlinal with outward dips of 20 to 40 degrees. It varies in thickness from an inch or two to 8 feet, but, taking into account the frequency of "horses" and "riders," the average workable thickness of pure mineral hardly exceeds 5 feet. Completely or nearly barren areas occur for the most part at those points where, instead of limestone, the schistose, highly weathered, rusty gneiss forms the roof.

Next above comes the Baderberg seam, called after the hill where it is worked. It is much more profitable than the Sattel, ranging from 10 to 20 feet in thickness, the average workable thickness of pure mineral being 8 feet or more.

The uppermost seam is the Vorwerk, and, although it shows a great thickness of graphitic rock, the thickness of workable graphite does not exceed 5 feet. Here and there are lenticles 20 feet thick. The Vorwerk graphite is mostly soft, but there is much hard stuff too which passes, deep down, into graphite-schist. Iron pyrites and porous brown iron ore are abundant – the latter probably a decomposition-product of the former. The presence of ferrous sulphate crystallized in little plates and granules is also noted.

So far as quality is concerned, the Sattel seam takes the first place, consisting almost entirely of soft flaky graphite, with but a few bands of hard mineral. In the Baderberg seam, there is a greater proportion of hard graphite, and in the Vorwerk seam still more.

The author regards the graphite as the highly metamorphosed representative of beds of vegetable detritus, dating from the oldest geological period known. Its present condition is the result, firstly, of contact-metamorphism induced by the amphibolites ; and, secondly, of the thrust-movements which ridged up into folds the rocks wherein lies the graphite. The seams themselves show the effects of enormous pressure, being in many places crushed and folded.

Detailed descriptions are given of the method of working and the plant employed, together with descriptive vertical sections of the mines. The graphite is washed on the spot, and, packed in barrels according to quality, finds a ready sale in Hungary, Germany, and England. The total annual production of raw mineral averages 45,384 cwts., and of "refined" mineral 28,612 cwts.

Magnetite is worked on the roof of the Sattel seam at one point. It contains 42·18 per cent. of metallic iron. Antimony glance is got from a vein in serpentine-impregnated limestone, where it is associated with mispickel, zinc-blende, galena, etc. ; but it does not pay to work at the present price of antimony. L. L. B.

II.—REPORT OF THE CORRESPONDING SOCIETIES COMMITTEE OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, TORONTO, 1897.*

The following Corresponding Societies nominated delegates to the Toronto meeting:—The Federated Institution of Mining Engineers, Archibald Blue; North of England Institute of Mining and Mechanical Engineers, W. Hamilton Merritt.

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The first meeting of the Conference was held in the University of Toronto on Thursday, August 19.

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At the Liverpool Conference, the question of federation amongst the local Natural History Societies of Great Britain had been referred to the Corresponding Societies Committee.

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The Chairman, in inviting discussion, said that there were great differences of opinion with regard to federation, but he thought that much good might result from some such scheme as the grouping of counties for occasional meetings of their local societies, if for no other purpose than to avoid duplication of work. By the proceedings of local societies being collected into one publication, diffuseness would be avoided, and the money spent by individual societies upon printing might profitably be diverted into other channels.

Mr. R. E. Dodge (New York) mentioned the Scientific Alliance of New York as having accomplished something by union, the announcement of meetings being satisfactorily made in the *Bulletin* of the Alliance, and the libraries of the different societies being kept together in one building. At Washington, the Joint Commission, on which all the Government scientists are represented, was formed on similar lines.

Mr. Hopkinson said that there were various ways in which federation could be carried out, which he might roughly group under three heads—amalgamation, union, and co-operation with representation. He instanced the Caradoc and Severn Valley Field Club as a good example of the benefit of amalgamation, a strong field club doing good local work, and publishing the results, having been formed by the coalition of two societies which were struggling for existence. The advantages of union without amalgamation were well illustrated by the Yorkshire Naturalists' Union, each society composing it being quite independent, but meeting together at an annual congress in different Yorkshire towns. Amongst its members were several Yorkshiremen, like himself not now residing in the county nor being members of any of the affiliated societies. The publications of the Union were devoted to the meteorology, geology, botany and zoology of Yorkshire. Under the third heading might be cited the present Conference, or such societies represented as were co-operating with Committees of Research of the British Association; while there were several intermediate links between the three grades of union. Federation, therefore, did not imply sacrifice of individuality.

Section C.

Mr. G. W. Lamplugh called attention to the appointment of a Committee of this Section for obtaining a collection of Canadian Geological Photographs, on the same lines as the British Committee.

Section D.

Mr. W. E. Hoyle urged the importance of the accurate use of generic and specific names in the publications of local societies. In particular, when naming new species, full and accurate descriptions should always be given.

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The second meeting of the Conference was held in the University of Toronto on Monday, August 23.

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The following Societies have been added to the list of the Corresponding Societies:—

1. The Halifax Scientific Society and Geologists' Field Club.
2. The Brighton and Sussex Natural History and Philosophical Society.
3. The Andersonian Naturalists' Society.

Committees appointed by the General Committee at the Toronto Meeting in August, 1897.

1.—Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.	Grants.
		£ s. d.
Seismological observations	*Chairman.*—Mr. G. J. Symons. *Secretaries.*—Dr. C. Davison and Prof. J. Milne. Lord Kelvin, Prof. W. G. Adams, Dr. J. T. Bottomley, Sir F. J. Bramwell, Prof. G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Mr. G. F. Deacon, Prof. J. A. Ewing, Prof. C. G. Knott, Prof. G. A. Lebour, Prof. R. Meldola, Prof. J. Perry, Prof. J. H. Poynting, Dr. Isaac Roberts, Dr. G. M. Dawson, Prof. T. G. Bonney, Mr. C. V. Boys, Prof. H. H. Turner, and Mr. M. Walton Brown.	15 0 0
The collection, preservation, and systematic registration of photographs of geological interest.	*Chairman.*—Prof. J. Geikie. *Secretary.*—Prof. W. W. Watts. Prof. T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, R. H. Tiddeman, J. J. H. Teall, J. G. Goodchild, H. Coates, and C. V. Crook.	10 0 0
To study life zones in the British Carboniferous rocks. [Balance of last year's grant.]	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Mr. E. J. Garwood. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Dr. Wheelton Hind, Dr. G. J. Hinde, Mr. P. F. Kendall, Mr. J. W. Kirkley, Mr. R. Kidston, Mr. G. W. Lamplugh, Prof. G. A. Lebour, Mr. G. H. Morton, Prof. H. A. Nicholson, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Prof. R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Prof. T. G. Bonney, Mr. W. Whitaker, Mr. Cuthbert Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, and Prof. W. W. Watts.	25 0 0
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2.—Not Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.
To confer with British and foreign societies publishing mathematical and physical papers as to the desirability of securing uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman.*—Prof. S. P. Thompson. *Secretary.*—Mr. J. Swinburne. Prof. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Prof. A. W. Rücker, and Dr. G. Johnstone Stoney.
The rate of increase of underground temperature downwards in various localities of dry land and under water.	*Chairman.*—Prof. J. D. Everett. *Secretary.*—Prof. J. D. Everett. Prof. Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Prof. Edward Hull, Dr. C. Le Neve Foster, Prof. A. S. Herschel, Prof. G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Prof. Michie Smith, and Prof. H. L. Callendar.
To consider the best methods for the registration of all type specimens of fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Prof. H. G. Seeley, and Mr. H. Woods.
The collection, preservation, and systematic registration of Canadian photographs of geological interest.	*Chairman.*—Prof. A. P. Coleman. *Secretary.*—Mr. Parks. Prof. A. B. Willmott, Prof. F. D. Adams, Mr. J. B. Tyrrell, and Prof. W. W. Watts.
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THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1897-98.

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204, George Street, Glasgow. Alex. Ross and D. Dewar	180	None	2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C. ..	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	250	None	£1 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1862..	Belfast Nat. F. C. ..	Museum, College Square. F. J. Bigger, M.R.I.A.	500	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831..	Berwickah. Nat. Club ..	Dr. J. Hardy, Old Cambus, Cockburnspath, N.B., and Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10s. 6d.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Mason College, Birmingham, W. P. Marshall and W. Boulton	266	None	£1 1s.	Journal, bi-monthly; Proceedings, annually.
Brighton and Sussex Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	Museum, Church Street, Brighton. E. A. Pankhurst	185	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862 ..	Bristol Nat. Soc. ..	Theodore Fisher, M.D., 25, Pembroke Road, Clifton, Bristol	167	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5, Chapel Street, Peterhead	160	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc..	Thomas Gibbs, 30, High Street, Burton-on-Trent	200	None	5s.	Annual Report. Transactions, occasionally
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C...	H. E. Forrest, 37, Castle Street, Shrewsbury	183	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867 ..	Cardiff Nat. Soc. ..	Walter Cook, 98, St. Mary Street, Cardiff	456	None	10s. 6d.	Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci...	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shepheard	620	None	5s.	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15, Cavendish Street, Chesterfield	384	£1 1s. None	Members, 31s. 6d.; { Associates and Students, 20s.	"Transactions of The Federated Institution of Mining Engineers," about every month.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	270	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc. ..	John B. Cornish, Penzance	68	None	£1 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C. ..	Public Hall, Croydon. R. F. Grundy	235	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C. ..	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	355	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885..	Dublin N. F. C.	Prof. T. Johnson, 12, Gilford Road, Sandymount, Dublin	230	5s.	5s.	"Irish Naturalist," monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	E. J. Chinnock, LL.D., Grey Friars', Dumfries	216	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc. ..	19, Watling Street, Canterbury. Stephen Horsley	83	None	10s. 6d.	"South Eastern Naturalist," annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1897-98.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, Tylehurst, Kirkcaldy, N.B	10 Societies, 900 Membs.	None	Assessment of 4d. per member	Proceedings, occasionally.
Edinburgh Geological Society, 1834..	Edinb. Geol. Soc. ..	H. M. Cadell, B.Sc., 5, St. Andrew Square, Edinburgh	150	10s. 6d.	12s. 6d.	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7, Knighton Villas, Buckhurst Hill, Essex	350	None	15s.	"Essex Naturalist," quarterly, and "Special Memoirs."
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng. ..	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, about every month.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc. ..	J. Barclay Murdoch, Capelrig, Mearns, Glasgow	240	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc. ..	S. M. Wellwood, 207, Bath Street, Glasgow	332 Members 30 Associates	7s. 6d. None	Members 7s. 6d. Associates 5s.	Transactions and Proceedings, annually
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc. ..	John Mayer, 207, Bath Street, Glasgow	640	£1 1s.	£1 1s.	Proceedings, annually; occasional papers.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C. ..	Literary and Philosophical Society's Rooms. Arthur Crabtree	130	None	2s. 6d.	"Halifax Naturalist," every two months
Hampshire Field Club, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts. N. H. Soc. ..	John Hopkinson, F.L.S., The Grange, St. Albans	230	10s.	10s.	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C. ..	A. J. Crosfield, Carr End, Reigate	85	10s.	10s.	Proceedings, every two or three years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc. .	E. G. Critchley, 23, High Street, Inverness	160	None	5s. and 2s.	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland ..	W. Lawson, 35, Molesworth Street, Dublin	100	None	£1.	Journal, annually.
Leeds Geological Association, 1874 ..	Leeds Geol. Assoc. ..	Dr. D. Forsyth, 2, Lifton Place, Leeds	90	None	5s. and 2s. 6d.	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B Wilson, Westfield, Armley, Leeds; W. S. Crowther, 4, Aberdeen Walk, Armley, Leeds	180	None	6s	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. J. M. Gimson	320 Members & Associates.	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875..	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	363	None	Resident, £1 1s.; Non-res., and Students, 10s. 6d.	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc. ..	Capt. E. C. Dubois Phillips, R.N., 14, Hargreave's Buildings, Chapel Street, Liverpool	690	None	£1 1s.	Report, annually; papers occasionally.
Liverpool Geological Society, 1858 ..	Liv'pool Geol. Soc ..	Royal Institution. H. C. Beasley	53	None	£1 1s.	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit Phil. Soc..	Royal Institution. J. Maxwell McMaster	214	None	£1 1s.; Ladies, 10s. 6d.	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc..	Museum, Yorkersgate, Malton, Yorkshire. Rev. S. Jenkinson	85	None	5s. and 2s. 6d.	Science Notes, monthly.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1897–98.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	146	2s. 6d.	Gentlemen, 7s.6d. Ladies and Non-Residents, 5s.	Yn Lioar Manninagh, occasionally.
Manchester Geographical Society, 1884	Manch. Geog. Soc. ..	Eli Sowerbutts, F.R.G.S., 16, St. Mary's Parsonage, Manchester	800	None	Members, £1 1s.; Associates, 10s.6d.	Journal, quarterly; "Geography," monthly
Manchester Geological Society, 1838..	Manch. Geol. Soc. ..	5, John Dalton Street, Manchester. James Tonge and Joseph Crankshaw	229	None	£1.	Transactions, eight or nine parts per annum.
Manchester Microscopical Society, 1880	Manch. Mic. Soc. ..	E. C. Stump, 16, Herbert Street, Moss Side, Manchester	215	5s.	6s.	Transactions and Report annually.
Manchester Statistical Society, 1833 ..	Manch. Stat. Soc. ..	63, Brown Street, Manchester. F. E. M. Beardsall and T. Gregory	201	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick ..	350	1s. 6d.	3s. and 5s.	Report, annually.
Midland Institute of Mining, Civil and Mechanical Engineers, 1869	Mid. Inst. Eng.	T. W. H. Mitchell, Mining Offices, Barnsley	259	None	£1 10s.	"Transactions of The Federated Institution of Mining Engineers," about every two months.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, 3, Oxford Street, Norwich	256	None	5s.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,150	None	21s. and 42s.	"Transactions of The Federated Institution of Mining Engineers," about every month.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	400	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton N. H. Soc. ..	H. N. Dixon, M.A., 23, East Park Parade, Northampton	150	None	10s.	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Henry Wilkins, 352, Alfreton Road, Nottingham	160	2s. 6d.	5s.	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. ..	J. Gardner, 3, County Place, Paisley	342	5s.	7s. 6d.	Report, annually; Meteorological Observations, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc. ..	Museum, Public Buildings, Penzance. Dr. H. Montgomerie	79	None	10s. 6d.	Report, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. ..	Tay Street, Perth. S. T. Ellison ..	320	2s. 6d.	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105, Freehold Street, Rochdale	243	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878 ..	Rochester N. C.	John Hepworth, Linden House, Rochester	142	None	5s.	"Rochester Naturalist," quarterly.
Scotland, Mining Institute of	Mining Inst. Scot. ..	James Barrowman, Stanecacre, Hamilton, N.B.	479	None	31s. 6d. and 21s.	"Transactions of the Mining Institute of Scotland," six times each year.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1897-98. *Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription.	Title and Frequency of Issue of Publications
Somersetshire Archæological and Natural History Club, 1848	Som'setsh. A.N.H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	580	10s. 6d.	10s. 6d.	Proceedings, annually
South African Philosophical Society, 1877	S. African Phil. Soc. ..	L. Péringuey, South African Museum, Cape Town	88	None	£2	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1887	S. Staff. Inst. Eng. .	Alexander Smith, M. Inst. C.E., 3, Newhall Street, Birmingham	107	£1 1s. and 10s. 6d.	21s. 6d. and 21s.	"Transactions of The Federated Institution of Mining Engineers," about every month.
Tyneside Geographical Society, 1887 ..	Tyneside Geog. Soc. ..	Geographical Institute, Barras Bridge, Newcastle-upon-Tyne. G. E. T. Smithson	1,200	None	10s. and 5s.	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. ..	Museum, Warwick. S. S. Stanley, 3, Regent Grove, Leamington	90	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. ..	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	210	10s.	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	165	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861 ..	Yorks. Nat. Union ..	W. Denison Roebuck, F.L.S., 259, Hyde Park Road, Leeds	457 and 2,567 Associates	None	Members 10s. 6d.; Associates 1d.	Transactions, annually; "The Naturalist," monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. ..	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	450	None	£3	Report, annually.

INDEX OF THE MORE IMPORTANT PAPERS, AND ESPECIALLY THOSE REFERRING TO LOCAL SCIENTIFIC INVESTIGATIONS, PUBLISHED BY THE ABOVE-NAMED SOCIETIES DURING THE YEAR ENDING JUNE 1, 1897.*

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Clark, J. Edmund ..	Note on the January High Barometer	Yorks. Phil. Soc. ..	*Report*	For 1896	36-37	1897
Cole, William	Earth Noises and supposed Slight Earthquake at Mersea and Colchester ..	Essex F. C.	*Essex Naturalist*	IX.	230-231	1896
Markham, C. A.	The Great English Earthquake, December 17, 1896	N'ton. N. H. Soc. ..	*Journal*	,,	151-155	1897
Parsons, Dr. H. F. ..	Some further Observations on Earth Temperatures	Croydon M. N. H. C. ..	*Trans.*	1895-96	175-179	1896
Percy, R. F.	The Determination of, and Use of, the Magnetic Meridian in Mine-surveying	Chest. Mid. Count. Inst.	*Trans. Fed. Inst.*	XII.	581-584	1897
,, ,, ...	An Improved Protractor	,, ...	,, ...	,,	585-589	,,
.. ..	.. ..	.. .. ..	.. .. ..	..	..	..

* The Titles of Papers on other than Mining and Mechanical Engineering, etc., have not been reprinted.

Section B.—CHEMISTRY.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Clowes, Prof. F.	The Detection and Estimation of Carbon Monoxide in the Air by the Flame Cap Test	Fed. Inst. Min. Eng. ..	*Trans.*	XIII.	71-73	1897
Coquillion, J.	Determination of Fire-damp in French Collieries	,, ,, ..	,, ...	..	65-68	..
Haldane, J. S.	Investigations on the Nature and Sources of the Suffocative Gas met with in Wells, together with further Observations on the Black Damp of Coal-mines	,, ,, ..	*Trans. Fed. Inst.*	XI.	265-273	1896
	The Causes of Death in Colliery Explosions	Midland Inst. Eng. ..	,, ,, ..	,,	502-513	,,
Hall, H.	Some Aspects of recent Colliery Explosions	N. Eng. Inst.	,, ,, ..	..	526-534	..
,, ,, ...	The Cost and Efficiency of Safety Explosives as Compared with Gunpowder	Fed. Inst. Min. Eng. ..	,, ,, ..	XIII.	4-21	1897
Orsman, W. J.	Notes on the Explosion of Coal-dust	N. Eng. Inst.	,, ,, ..	XI.	536-539	1896
Sexton, Prof. A. H. ..	The By-products of the Blast-furnace	Glasgow Geol. Soc. ..	*Proc.*	XXVII.	122-135	..
Stuart, D. M. D.	The Phenomena of Colliery Explosions	Fed. Inst. Min. Eng. ..	*Trans. Fed. Inst.*	XII.	371-381	1897
Winkhaus, Bergassessor F.	Further Experiments with Explosives	N. Eng. Inst.	,, ,, ..	,,	32-49	1896
,, ,,	The Danger of Employing Safety Fuzes for Blasting in Fiery Mines	,, ,, ..	,, ,, ..	,,	160-176	,,
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Section C.—GEOLOGY.

Anderson, James.. ..	Evidences of the most recent Glaciers in the Firth of Clyde District	Glasgow Geol. Soc. ..	*Trans.*	X.	198-209	1896
Barke, F.	Sectional Report—Geology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	79 84	,,
Beasley, H. C.	Classification of the Footprints from the Trias in Cheshire and Lancashire ..	Liv'pool Geol. Soc.	*Proc.*	VII.	391-409	,,
Bell, Alfred	A Synopsis of the Crustacea and Echinodermata of the Upper Tertiaries ..	Yorks. Phil. Soc. ..	*Report*	For 1896	1-12	1897
Bell, Dugald	On the High-level Shelly Deposits, and their bearing on the Question of Submergence, with Special Reference to the recent (Third) Edition of Dr. James Geikie's *Great Ice Age*.	Glasgow Geol. Soc. .	*Trans.*	X.	346-348	1896
Bergeron, J.	Possible Extensions of the Coal-fields of France	Fed. Inst. Min. Eng. ..	,, ...	XII.	335-357	1897
Bladen, W. Wells ..	On the Osseous and other Remains found at Stone	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	108-115	1896
Bradshaw, C.	Ripple-marked Sandstone at Grimesthorpe, Sheffield	Yorks. Nat. Union ..	*The Naturalist* ..	For 1896	319-320	,,
Brady, F., G. P. Simpson, and Nath. R. Griffith	The Kent Coal-field	N. Eng. Inst.	*Trans. Fed. Inst.*	XI.	540-550	,,
Brodie, Rev. P. B. ..	On the Sandstones in the Upper Keuper in a part of Warwickshire, Six Miles North-west of Warwick	Warw. N. A. F. C. ..	*Proc.*	41	36-39	1897
Bunkell, H. B.	Notes on the Venterskroom Gold-fields, South African Republic	N. Eng. Inst	*Trans. Fed. Inst.*	XII.	186-189	1893
Callaway, Dr. C.	A Sketch of the Process of Metamorphism in the Malvern Crystallines ..	Liv'pool Geol. Soc. ..	*Proc.*	VII.	453-460	..
Campbell, Rev. Jos. ..	The Gold-fields of the Hauraki Peninsula, New Zealand	N. Eng. Inst.	*Trans. Fed. Inst.*	XII.	462-482	1897
Churchill, J. M.	The Geology of Pontypool	Cardiff Nat. Soc. ..	*Trans.*	XXVIII.	94-103	,,
Close, Rev. M. H. ..	The former Abundance of Granite Boulders in the South-east Neighbourhood of Dublin	Dublin N. F. C.	*Irish Naturalist* ..	VI.	29-33	,,

Section C.—GEOLOGY.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Coates, Henry	Annual Address (Scenes in the Geological History of the Site of Perth)	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	cvii.-cx.	1896
Coke, G. E.	Southern Limit of the Nottinghamshire Coal-field	Fed. Inst. Min. Eng.	*Trans.*	XI.	339-341	,,
Cole, Prof. G. A. J.	Oldhamia in America	Dublin N. F. C.	*Irish Naturalist*	V.	254-255	,,
,, ,,	A Proposed Geological Photographic Survey of the Counties of Dublin and and Wicklow	,, ,,	,, ,,	VI.	125-126	1897
Collins, J. H.	Notes on Cornish Fossils	Cornw. R. Geol. Soc.	*Trans.*	XII. Pt II.	65-70	,,
Cooke, John H.	Work for Lincolnshire Geologists	Yorks. Nat. Union	*The Naturalist*	For 1896	205-210	1896
,, ,,	A Section in the Lower Oolites of Scarborough	,, ,,	,, ,,	,,	289-292	,,
,, ,,	Lincolnshire Boulders	,, ,,	,, ,,	For 1897	103-105	1897
Craig, Robert	Remarks upon "Joints" or Natural Fractures in Limestones	Glasgow Geol. Soc.	*Trans.*	X.	210-215	1896
De Rance, C. E.	Notes on the Geological Features of the Coast of North Wales from Liverpool to Menai Bridge	N. Eng. Inst.	*Trans. Fed. Inst.*	XI.	552-555	,,
,, ,,	The River Weaver and its Salt Beds	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	128-129	,,
Dickson, E., and P. Holland	Analyses of Triassic Rocks from the Neighbourhood of Liverpool	Liv'pool Geol. Soc.	*Proc.*	VII.	443-452	,,
Dunston, George	The Eastern Extension of the Midland Coal-field and the Exploration at Southcar	Midland Inst. Eng.	*Trans. Fed. Inst.*	XII.	515-22	,,
Fisher, Rev. Osmond	The Geology of the Portesham District	Dorset N. H. A. F. C.	*Proc.*	XVII.	194-9	,,
Geikie, Sir A.	The Latest Volcanoes of the British Isles	Glasgow Geol. Soc.	*Trans.*	X.	179-9	,,
Gibson, Walcot	The Geology of Africa in Relation to its Mineral Wealth	Fed. Inst. Min. Eng.	,,	XII.	303-322	1897
Gray, William	The Origin and Present Condition of the Giant's Causeway	Belfast N. F. C.	*Report and Proc.*	IV.	257-262	,,
Grensted, Rev. F. F.	The Dynamical Theory of the Craven Highlands	Liv'pool Geol. Soc.	*Proc.*	VII.	377-383	1896
Gresley, W. S.	The Yorkshire and Nottinghamshire Coal field: Geological Suggestions Relative to its Eastward Extension Beneath the Permian and Secondary Strata into Lincolnshire	Ches Mid. Count. Inst.	*Trans. Fed. Inst.*	XI.	143-153	,,
Harker, Alfred	In Memoriam: Alexander Henry Green	Yorks. Nat. Union	*The Naturalist*	For 1897	111-114	1897
Harrison Rev. S. N.	Report of Geological Section	I. of Man N. H. A. Soc.	*YnLiorManninagh*	III.	120-121	1896
Holmes, T. V.	A Sketch of the Geology of Epping Forest	Essex F. C.	*Essex Naturalist*	IX.	160-165	,,
,, ,,	Notes on the Ancient Physiography of South Essex	,, ,,	,, ,,	,,	193-200	,,
,, ,,	The Relation of Palæolithic Man to the Glacial Epoch	,, ,,	,, ,,	,,	245-247	1897
,, ,,	The Palæolithic Deposits at Hitchin, and their Relation to the Glacial Epoch (Report to the Royal Society by Mr. Clement Reid)	,, ,,	,, ,,	X.	49-51	,,
Howard, F. T.	An Ichthyosaurus Jaw from the Lias of Lower Penarth	Cardiff Nat. Soc.	*Trans.*	XXVIII.	71-72	1896
,, ,,	A Deep Well Boring (1,063 feet) at Cardiff Docks	,, ,,	,, ,,	,,	72-74	,,
,, ,,	The Geology of the East Barry Dock, with Notes on the Supposed Coal-fields of South Glamorgan	,, ,,	,, ,,	,,	77-83	1897
Howard, F. T., and Evan W. Small	Geological Notes on Skomer Island	,, ,,	,, ,,	,,	55-60	1896
Howard, F. T., and T. H. Thomas	Note on Eophrynus found at Ty'nybedw by W. O'Connor	,, ,,	,, ,,	,,	52-54	,,
Jeffs, Osmund W.	The Origin and Characteristics of our British Scenery	Manch. Geol. Soc.	*Journal*	XI.	265-266	,,
Jukes-Browne, A. J.	On a Collection of Fossils from the Upper Greensand in the Dorset County Museum	Dorset N. H. A. F. C.	*Proc.*	XVII.	96-108	,,
Kincaid, James	Coal: Its Origin and Use (Lecture)	Buchan F. C.	*Trans.*	IV.	17-19	1897
Landon, Joseph	Underground Water Channels	Birm. N. H. Phil. Soc.	*Journal*	II.	83-86	,,

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
La Touche, Rev. J. D.	Further Notes on the Geology of the Brown Clee District	Woolhope N. F. C.	*Trans.*	1893-94	15-19	1896
Launay, L. de	Geological Description of the Gold Mines of the Transvaal (Witwatersrand, Heidelberg, and Klerksdorp Districts)	Fed. Inst. Min. Eng.	"	XI.	378-459	"
Lomas, J.	Observations on recent Glacial Striæ in Switzerland	Liv'pool Geol. Soc.	*Proc.*	VII.	383-387	"
Longridge, Capt. C. C.	Mining in Northern Argentina	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XII.	327-334	1897
Louis, Henry	Note on the Tellurium Mineral of Choukpazat	N. Eng. Inst.	" "	"	513	"
McLennan, J. S	The Coast Line of Berwickshire from Eyemouth to Marshall Meadows Bay	Glasgow Geol. Soc.	*Trans.*	X.	337-345	1896
McNair, Peter	On the Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone	" "	"	"	302-317	"
Mansel-Pleydell, J. C.	On the Footprints of a Dinosaur (Iguanodon?) from the Purbeck Beds of Swanage	Dorset N. H. A. F. C.	*Proc.*	XVII.	115-122	"
Marshall, J. W. D.	Notes on the British Brachiopoda: Part I.	Bristol Nat. Soc.	"	VIII.	17-40	"
Meachan, F. J.	Bumps and Outbursts of Coal	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	XII.	612-615	1897
Metcalfe, A. T.	The Gypsum Deposits of Nottinghamshire and Derbyshire	Ches. Mid. Count. Inst.	" "	"	107-114	1896
" "	The Tertiary Lava Fields of the West Coast of Scotland	Nott. Nat. Soc.	*Report*	44	1-12	"
Meyrick, E.	List of Cretaceous Fossils of the Marlborough District	Marlb. Coll. N. H. Soc.	"	45	55-57	1897
Millett, F. W.	The Foraminifera of the Pliocene Beds of St. Erth in relation to those of other Deposits	Cornw. R. Geol. Soc.	*Trans.*	XII. Pt. II.	43-46	"
Mitchell, D. J.	The Greensand at Moreseat	Buchan F. C.	"	IV.	30-32	"
Neilson, James	On the Occurrence of Marine Organisms in the Boulder Clay of the Glasgow District. Part I.	Glasgow Geol. Soc.	"	X.	278-279	1896
" "	" " Part II.	" "	"	"	273-277	"
" "	On the Old Red Sandstone and Carboniferous Rocks of the North End of the Island of Arran	" "	"	"	280-301	"
Newby, John R.	The Earthquakes in Iceland, 1896	Manch. Geol. Soc.	*Journal*	XII.	174-187	1897
O'Connor, W.	On several Fossils, including a "Spider" (*Eophrynus*) from the 9-feet Coal-seam at Ty'nybedw, Rhondda Valley	Cardiff Nat. Soc.	*Trans.*	XXVIII.	50-52	1896
Parsons, Cyril E.	The Deposit at the Mill Close Lead Mine, Darley Dale, Matlock	Ches. Mid. Count. Inst.	*Trans. Fed. Inst.*	XII.	115-121	"
Piper, G. H.	Geology of the District near Ledbury	Woolhope N. F. C.	*Trans.*	1893-94	22-23	"
Polwhele, T. R.	Anniversary Address	Cornw. R. Geol. Soc.	"	XII. Pt. II.	9-18	1897
Praeger, R. Ll.	A Submerged Pine Forest	Dublin N. F. C.	*Irish Naturalist*	V.	155-160	1896
Pratt, Dr. R.	A Visit to the Upper Cretaceous System at Eastbourne	Leicester Lit. Phil. Soc.	*Trans.*	IV.	258-266	"
Prentice, James	The Mineral Seams of New Monkland	Mining Inst. Scot.	"	XVIII.	37-51	"
Preston, Henry	Some Account of the Surface Geology of the District North of Grantham	Yorks. Nat. Union	*The Naturalist*	For 1896	285-288	"
Reade, T. Mellard	Presidential Address: British Geology in relation to Earth Folding and Faulting	Liv'pool Geol. Soc.	*Proc.*	VII.	363-377	"
" "	Foraminiferal Boulder Clay at Great Crosby, and at Blackpool	" "	"	"	387-390	"
" "	The Drift of the Mid-Wales Coast	" "	"	"	410-419	"
" "	The Berwickshire Coast: a Study in Physical Geology	" "	"	"	420-443	"
Reid, James, and Peter Macnair	On the Genera *Lycopodites* and *Psilophyton* of the Old Red Sandstone Formation of Scotland	Glasgow Geol. Soc.	*Trans.*	X.	323-330	"
Roberts, S.	The Submarine Forest Bed at Maenporth, near Falmouth	Cornw. R. Geol. Soc.	"	XII. Pt. II.	58-64	1897
Sharman, G., and E. T. Newton	Cretaceous Fossils from the Drift of Moreseat, Aberdeen	Buchan F. C.	"	IV.	26 30	"
Sheppard, Thos.	Notes on the Occurrence of Boulders of Shap Granite, &c., in Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1896	333-339	1896

Section C.—GEOLOGY.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Sheppard, Thomas ..	Lincolnshire Boulders..	Yorks. Nat. Union ..	*The Naturalist* ..	For 1896	373	1896
Simpson, William ..	Some Physiographical and Geological Features of the Parish of Halifax ..	Halifax S. S. G. F. C. ..	*Halifax Naturalist*	I.	2-6, 26-29	,,
,, ,, ..	The Strata of the Parish of Halifax	,, ,, ..	,, ,,	,,	69-77	,,
Smith, John"	A New View of the Arran Granite Mountains	Glasgow Geol. Soc. ..	*Trans.*	X.	216-256	,,
,, ,, ...	Charred Coal with Graphite, and Discovery of Diamonds in the Graphite at Craigman, New Cumnock	,, ,, ..	,, ...	,,	257-262	,,
,, ,, ...	On the Discovery of Fossil Microscopic Plants in the Fossil Amber of the Ayrshire Coal-field	,, ,, ..	,, ...	,,	318-322	,,
,, ,, ...	Dry River Channels in the Neighbourhood of Muirkirk	,, ,, ..	,, ...	,,	331-333	,,
,, ,, ...	On the Occurrence of Pumice Pebbles in the Raised Beaches of Ayrshire ..	,, ,, ..	,, ...	,,	349-353	,,
Spencer, James	Erratics of the Calder Valley	Halifax S. S. G. F. C. ..	*Halifax Naturalist*	I.	20-25 45-50	,,
Stanley, S. S.	The Origin of Gravel Beds, illustrated in some Local Drifts	Warw. N. A. F. C. ..	*Proc.*	41	15-19	1897
Stephens, Francis J. ..	The Morte Slates, as described by Dr. Hicks	Cornw. R. Geol. Soc. ..	*Trans.*	XII. Pt. II.	47-48	,,
,, ,, ..	On an Altered Ashbed at Penryn	,, ,, ..	,, ,,	,,	49-57	,,
Tate, Thomas"	The Yorkshire Boulder Committee and its Tenth Year's Work	Yorks. Nat. Union ..	*The Naturalist* ..	For 1897	59-74	,,
Thompson, Beeby ..	Pre-Glacial Valleys in Northamptonshire	N'ton N. H. Soc. ..	*Journal*	IX.	47-50	1896
,, ,, ..	The Junction Beds of the Upper Lias and Inferior Oolite in Northamptonshire	,, ,, ..	,, ...	,,	73-80, 131-149	1897
,, ,, ..	Ichthyosaurus from Corby	,, ,, ..	,, ,,	,,	80-81	,,
Tuckwell, Rev. W. ..	The Lincolnshire Naturalists' Union Boulder Committee	Yorks. Nat. Union ..	*The Naturalist* ..	For 1896	349-353	1896
Wardle, Thomas	The Geology of Cromer	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXX.	134-143	,,
Whitaker, Wm.	Some Essex Well-sections (Part IV.), with some Water Analyses	Essex F.C...	*Essex Naturalist*..	IX.	167-190	,,
Whitaker, Wm., & T. V. Holmes	Borings in Search of Coal in Suffolk and Essex	,, ,, ...	,, ,, ..	,,	213 218	,,
,, ,,	Boring in Search of Coal at Weeley, in Essex	,, ,, ...	,, ,, ..	,,	253-256	1897
,, ,,	Boring in Search of Coal in Essex—Reports	,, ,, ...	,, ,, ..	X.	9-10	,,
Wotton, F. W.	The Fauna and Flora of the Shell bed Deposits at East Barry Dock	Cardiff Nat. Soc. ..	*Trans.*	XXVIII.	90-93	,,
Wright, Joseph	Boulder Clay, a Marine Deposit. Part I.	Glasgow Geol. Soc. ..	,, ...	X.	263-269	1896
,, ,, ..	,, ,, Part II.	,, ,, ..	,, ...	,,	270-272	,,
Young, Dr. John ..	Notes on the Ostracoda found in the Lacustrine, or Freshwater, Strata of the Campsie District, which alternate with the Lower Beds of the Carboniferous Marine Limestone series	,, ,, ..	,, ...	,,	334-336	,,

Section D.—ZOOLOGY.

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Section E.—GEOGRAPHY.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Bowes, Ald. I.	The Suez Canal	Manch. Geog. Soc.	*Journal*	XII.	137-148	1897
,, ,,	Proposed Nicaragua Canal	,, ,,	,,	,,	149-156	,,
Crook, H. T.	On the Sale of Ordnance Survey Maps	,, ,,	,,	XI.	217-231	1896
* * *	* * * * * * * * *	* * *	* *	* *	*	* *

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Hoskold, H. D.	Notes upon Foreign Mining Laws and Adequate Areas for Mining Concessions	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	160-173	1897
* * *	* * * * * * * * *	* * *	* *	* *	*	* *

Section G.—MECHANICAL SCIENCE.

Bailey, Ernest J.	Saving Life in Colliery Explosions	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	XIII.	132-138	1897
Bell, W. R., and E. McGowan	Haulage at Wearmouth Colliery	N. Eng. Inst.	,, ,,	XI.	221-226	1896
Bramwell, Hugh	The Compound Winding Engine at the Great Western Colliery Company's Tymawr Pit: with Notes on its Comparative Steam Economy	Fed. Inst. Min. Eng.	,, ,,	XII.	282-288	1897
Bromly, A. H.	Notes upon Gold-mining in Burma	N. Eng. Inst.	,, ,,	,,	506-513	,,
Brown, Horace T.	Mechanical Roasting of Ores	Fed. Inst. Min. Eng.	,, ,,	XI.	369-377	1896
Brown, John	Automobiles, or Horseless Carriages	Belfast N. H. Phil Soc.	*Report and Proc.*	1895-96.	41-50	,,
Brown, John	Eccentric Haulage Clip	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	147	1897
Carrington, W.	Description of Various Types of Ropeways, and Remarks as to their Proper Selection	Fed. Inst. Min. Eng.	,, ,,	,,	91-102	,,
Chaplin, G. P.	Cornish Methods of Mine Timbering	N. Eng. Inst.	,, ,,	,,	200-210	,,
Charleton, A. G.	The Indian Gold-fields	Fed. Inst. Min. Eng.	,, ,,	XI.	345-368	1896
Clarke, T. B. A.	Electric Coal-cutting on Longwall Faces	Midland Inst. Eng.	*Trans. Fed. Inst.*	XI.	492-501	1896
Donkin, Bryan	Powdered Coal for Firing Steam Boilers: Wegener and other Systems	Fed. Inst. Min. Eng.	,, ,,	,,	321-332	,,
Durnford, H. St. J., and Roslyn Holiday	The Use of Electricity at Ackton Hall Colliery	Mid. Inst. Eng.	,, ,,	XIII.	232-239	1897
Edwards, Clements	Railways and their Relation to the Coal Trade	Fed. Inst. Min. Eng.	,, ,,	,,	107-117	,,
Fothergill, J. R.	Combustion in Marine Boilers	Liv'pool E. Soc.	,, ,,	XVII.	70-81	1896
Fowler, George	How a Mine may be Dry but not Dusty	Ches. Mid. Count. Inst.	*Trans.*	XI.	128-135	,,
Gallow ay, W.	Secondary Haulage	Fed. Inst. Min. Eng.	*Trans. Fed. Inst.*	XII.	257-262	1897
,, ,,	The Principal Pumping Engine at Llanbradach Colliery	,, ,,	,, ,,	,,	294-299	,,
,, ,,	Appliances for Winding Water	,, ,,	,, ,,	XIII.	74-84	,,
Gobert, A.	The Gobert Freezing Process of Shaft Sinking	,, ,,	,, ,,	XI.	297-304	1896
Hastie, James	Sinking, Surface-fittings, and Coal-cleaning Plant at Whistleberry Colliery, Hamilton	Mining Inst. Scot.	*Trans.*	XVIII.	56-63	1897
Head, Jeremiah	The Coal Industry of the South-eastern States of North America	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	177-190	,,
Holiday, Roslyn	The Application of Electricity to Mining Operations	Fed. Inst. Min. Eng.	,, ,,	XII.	2-12	1896

Section G.—MECHANICAL SCIENCE.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published
Hollis, H. W. ..	A Spring Coupling for Winding or Hauling Ropes	N. Eng. Inst. ..	*Trans. Fed. Inst.*	XII.	182-184	..
Home, William ..	Lifting a Vertical Rising Main by Expansion	Ches. Mid. Coun. Inst.	.. ..	..	105-106	..
Lichtenberger, Th. ..	Honigmann System of Boring and Sinking Shafts	N. Eng. Inst. ..	.. ..	XIII.	155-159	1897
McLaren, John ..	Road Locomotives	Fed. Inst. Min. Eng.	.. ..	XI.	279-291	1896
Maltby, Henry E. ..	The Enlargement of a Shaft at Lidgett Colliery without Interruption of Coal-winding	Mid. Inst. Eng.	.. ..	XII.	642-644	1897
Musker, Arthur	Artificial Paving Slabs	Liv'pool E. Soc.	*Trans.*	XVII.	31-39	1896
Noble, Algernon, and Norman Nisbet	Notes on Coal-mining	N. Eng. Inst.	*Trans. Fed. Inst.*	XIII.	141-146	1897
Piggford, Jonathan ..	Electric Haulage at Pleasley Colliery	Mid. Inst. Eng... Ches. Mid. Coun. Inst.	.. ..	XII.	633-636	..
Ravenshaw, H. W. ..	Precautions necessary in the Use of Electricity in Coal Mines	Fed. Inst. Min. Eng.	.. ..	XI.	306-315	1896
Ross, Alexander ..	Light Railways: Conditions affecting their Construction and Working ..	Liv'pool E. Soc.	*Trans.*	XVII.	128-143	..
Scott, W. G.	Description of a Locomotive Depot for the Accommodation of 180 Engines and Tenders	.. ..	.. .. ..	..	21-34	..
Shaw, Saville	The Education of Metallurgists	N. Eng. Inst.	*Trans. Fed. Inst.*	XII.	488-494	1897
Simpson, F. R.	Notes on the Sinking of 2 Shafts at Claravale Colliery, near Wylam-upon-Tyne	.. .. ..	.. ..	XIII.	193-199	..
Smith, C. Sebastian ..	Safety props for Supporting Cages in the Head-gear of Pits in cases of Over-winding	Ches. Mid. Coun. Inst.	.. ..	XII.	564-568	..
Trestrail, N.	The Duty of Cornish Pumping Engines, Past and Present, and as compared with others	S. Staff. Inst. Eng. .	.. ..	..	548-561	..
Walker, G. Blake ..	The Education of Mining Engineers (Presidential Address)	Mid. Inst. Eng.	.. ..	..	135-179	1896
Watson, Simeon	Pit-top Safety Fencing	Ches. Mid. Coun. Inst.	.. ..	..	122-123	..
Wight, W. D.	Anthracite Coal-breaking and Sizing Plant at Glynecastle Colliery	Fed. Inst. Min. Eng. ..	.. ..	..	238-245	1897
.. ..	Automatic Variable Expansion Gear applied to Balanced Slide-valve Winding Engines	.. .. ..	.. ..	..	279-281	..
Yates, John	The MacArthur-Yates Process of Gold Extraction: Dry Crushing with Direct Amalgamation and Cyanidation	.. .. ..	.. ..	..	361-365	..
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Section H.—ANTHROPOLOGY.

Chinnock, Dr. E. J. ..	A Prehistoric Chisel	Dum. Gal. N. H. A. Soc.	*Trans.*	12	90-93	1897
Dale, W.	Ancient Bronze Weapons from the Neighbourhood of Southampton	Hants. F. C.	*Proc.*	III.	265-266	..
Mansel-Pleydell, J. C. ..	On a Romano-British Brick Kiln and a British Barrow at Bagber, Milton Abbas, with an Historical Dissertation on Pottery and Brickmaking	Dorset N. H. A. F. C. ..	.. ..	XVII.	127-134	1896
* * *	* * * * * * * * *	* * *	* * *	* * *	* * *	* * *

Section I.—PHYSIOLOGY.

Barrowman, Jas.	The Health Conditions of Coal-mining	Mining Inst. Scot. ..	*Trans.*	XVII.	98-106	1896
Haldane, Dr. J. S. ..	The Causes of Death in Colliery Explosions	.. .. ..	.. .. ..	XVIII.	30-31	..
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Section K.—BOTANY.

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III.—HISTORICAL AND ARCHÆOLOGICAL MEMOIR ON THE IRON-WORKS OF THE SOUTH-EAST OF ENGLAND, (PARTICULARLY OF SUSSEX).*

By MARK ANTONY LOWER.

Before entering on the history of this manufacture, now extinct in this part of England, it may be as well to premise that the strata which produced the iron ore lie in the central portion of the Wealden formation, in the vast beds of sandstone constituting what is provincially called the Forest Ridge, and known among geologists as the Hastings Sand. These beds extend from Hastings, inland, in a direction nearly west, and form a ridge of elevated land, the course of which will be easily indicated by naming Ashburnham, Heathfield, Crowborough, Ashdown Forest, Worth, Tilgate Forest, and St. Leonard's Forest, as prominent points, the loftiest being Crowborough, which attains an elevation of 804 feet above the level of the ocean. This formation, which stretches on one hand to within a few miles of the chalk ridge known as the South Downs, and, on the other, to within a similar distance of the chalk hills of Kent and Surrey, was, in the earliest periods of historical record, one vast forest, designated Coit Andred, Andred's-Wald, or the Forest of Anderida. In the still more remote periods, the investigation of which belongs to geological science, it was first overflowed by the waters of an immense river, then submerged by those of a profound ocean, and, lastly, elevated by successive deposits to its existing form. It was in the first of these periods that the ferruginous matter, which was afterwards to become so useful for the purposes of mankind, had its origin. In a private letter with which the writer was favoured by his friend, the late Dr. Mantell, that distinguished geologist remarks:

"It is a very interesting fact that all our principal iron-works obtained their metal from the ferruginous clays and sands of the Wealden; in other words, from iron produced by vegetable and animal decomposition in the bed and delta of a mighty river, which flowed through countries inhabited by the iguanodon and other colossal reptiles."†

Another able geologist, Mr. P. J. Martin, whose opinion will also be received with great respect, observes:

"It appears to me that the ore in the Forest Ridge was the clay iron-stone of the 'Wealden Beds.' At the western extremity of the district it is thought that the ferruginous sands of the 'Lower Greensand' were used; but in the clay country of the Weald I have found sufficient evidence of the exclusive use of a comparatively recent concretion—a kind of 'bog-iron,' frequently turned up by

* Reprinted by permission of the Sussex Archæological Society, from their *Sussex Archæological Collections*, 1849, vol. ii., pages 169 to 220; and from *Contributions to Literature: Historical, Antiquarian, and Metrical*, 1854, pages 85 to 138.

† Dr. Mantell adds: "The great coal-field of Hanover is in the Wealden formation. What a pity that the forests of the iguanodon country which furnished the materials of those carboniferous strata drifted so far north! Had it not been so, we should have had abundance of coal in our Wealds, and Sussex might have furnished rivals to Manchester and Birmingham."

the plough, and called 'iron rag.' It is composed of clay, gravel, and perhaps about 25 or 30 per cent. of oxide of iron, and is a superficial and fragmentary formation—a recent 'pudding-stone.'"

To all who are acquainted with Sussex history, there is no fact more familiar than the former existence, to a great extent, of the manufacture of iron within its limits. Of the history of the trade, however, little has hitherto been known, or, if known, certainly never presented to public notice. Its origin was still further shrouded in mystery, and whether it should be assigned to the fifth, the tenth, or the fifteenth century was a matter of total uncertainty; and so it might have remained for years to come, but for the archæological acumen of the rector of Maresfield. To the Rev. Edward Turner, we are indebted for the discovery of the highly interesting fact, that it dates as far back as the period of the Roman dominion in Britain.

A most agreeable and important illustration of the now familiar truth that archæology is the best handmaid of history is furnished by Mr. Turner's researches. The maid, indeed, has in this case, been more trustworthy than her mistress; for history has transmitted us no record to show that the Romans were acquainted with the ferruginous riches of the Wealds, and it was left for the inductions of archæology to supply the omission. In the year 1844, Mr. Turner observed, upon a heap of cinders,* laid ready for use by the side of the London road, a small fragment of pottery, which on examination proved to be Roman. His curiosity having been excited by so unusual a circumstance, Mr. Turner ascertained, on inquiry, that the cinders had been dug upon Old Land Farm, in his own parish of Maresfield, and immediately contiguous to Buxted. He at once visited the spot, and found that the workmen engaged in the digging were exposing to view the undoubted remains of a Roman settlement.

The place in question is the site of one of the innumerable fields of iron scoriæ marking the localities of the extinct furnaces and forges of the Weald. The bed was originally of great extent, no less than 6 or 7 acres of it (varying in depth from 2 to 10 feet) having been already removed for the useful purpose referred to in the note. A few days previously to Mr. Turner's visit, the labourers had opened, in the middle of this field, a kind of grave, about 12 feet in depth, at the bottom of which lay a considerable quantity of broken Roman pottery, evidently the remains of a regular funeral deposit. The superincumbent stratification was as follows: the ground had been excavated, first, through about 1 foot of earth; then through a layer of cinders, 2 feet in thickness: and, lastly, through about 8 or 9 feet of earth. The cavity had been filled up entirely with cinders.

The digging had been carried on many months previously to Mr. Turner's investigations. About two years before, the foundations of a building, measuring according to the statement of the workmen about 30 feet by 12 feet were uncovered. They were very rudely constructed of stone, and lay about 6 feet beneath the surface. A human skeleton, in a very perfect state, was discovered at the same time, but it crumbled to dust on exposure to the air.

Mr. Barratt, the surveyor, by whom the workmen are employed, informs the writer that he has seen several skeletons exhumed from the cinder-bed, in which the bodies had been interred as in ordinary soil. If these were Roman interments—which can scarcely be questioned—we are led to suppose that they were made long

* The "scoriæ" of the disused furnaces are called "cinders," and are much employed for the repair of turnpike and other roads. That they have long borne this somewhat improper name appears not only from documents of ancient date, but from the designations of many localities in the iron district, as Cinderford, Cinderhill, Cindergill, &c.

subsequently to the original deposit of the scoriæ, since a recently-formed cinder-bed would have been a very unlikely spot to be selected for the burial of the dead. The fair inference from these considerations is, that the iron-works at this place were carried on by the Romans during a long series of years.

So extremely numerous are the remains of Roman pottery on the spot, that scarcely a barrow-load of cinders is driven out that does not contain several fragments of it. Hardly any of the vessels have been found entire,—a circumstance not to be wondered at, when we consider their fragile nature and the great weight of the superincumbent cinders.

At the Sussex Archæological Society's annual meeting, held at Lewes in August, 1848, the writer had the pleasure of exhibiting a collection of the various articles discovered during the progress of the digging; it is hardly necessary to add that many others had been overlooked, while many more had been thrown away as useless by the labourers, or sold for a trifle to casual passers-by, previously to the examination of the spot by competent observers. The objects most worthy of attention which have been rescued from destruction are—

1. Coins, in second brass, of Nero, Vespasian, and Tetricus, and a fragment much oxidized, of one of Dioclesian. Some have undergone the action of fire and cannot be identified. The Vespasian is of the most common occurrence.*

2. A brass fibula. Portions of other fibulæ, and of armillæ, were noticed by Mr. Turner.

3. Fragments of coarse fictile vessels, principally domestic. The pottery of this kind is in great quantities, and of great variety as regards shape, colour, and fineness. Several fragments of the vessels known as *mortaria* have the potters' names boldly stamped upon them, particularly IVCVN (for Jucundus?) and EVAI.

4. Fragments of fine red or Samian ware, both figured and plain. Several of these likewise bear potters' marks or stamps, particularly OF. (officinâ) MIRAVI, and IVAN or IVANI.

Fig. 1.

Fig. 1 is a beautiful shallow cup, 3¾ inches in diameter, and adorned upon the rim with the peculiar ornament of such frequent occurrence on Roman ware, and generally believed to represent the ivy leaf.

* The coins which the writer has inspected are as follows: Nero (A.D. 54-68), two; Vespasian (69-79), about eight or ten; Tetricus (circ. 274), one; Dioclesian (284-286), one or two. Of those which cannot be appropriated, some may belong to the intervening emperors. Until recently, the labourers have regarded these valuable relics as "old halfpence;" and according to their own unsophisticated statement, "chucked" them away, "because the letters on 'em was pretty near rubbed out!"

Figures 2 and 3 are also fragments of Samian. The man on Fig. 3 appears to be in the act of throwing the discus, a well-known Roman game.

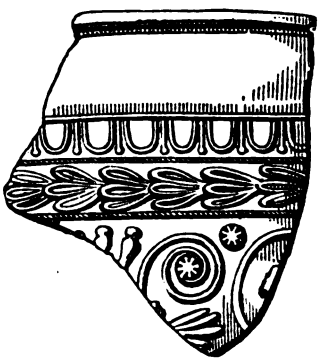


Fig. 2.

Fig. 3.

The writer caused these objects to be engraved, less from the idea that they exhibit any peculiarity, than for the purpose of proving that their workmanship is unquestionably Roman.

5. Fragments of glass.

6. Pieces of sheet-lead full of nail-holes, some of which had fragments of wood adhering to them. Much broken brick was also found.

7. An implement (Fig. 4) of mixed metal, very hard; probably a *stylus*.

Fig. 4.—Length about 5¼ inches.

In the absence of further evidence, the writer is unwilling to speculate largely upon the date of the commencement of these iron-works; but from the preponderance of the coins of Vespasian, we may hazard a conjecture that it took place during the reign of that emperor, or his successor, Titus, at a time when Agricola, then governor of Britain, was successfully introducing the arts of civilization into this island. That the works were still carried forward in Dioclesian's time is clear, from the coin of that monarch.

It is worthy of remark, that the Romans would appear, so far at least as the evidence of the discovery under notice goes, to have been but imperfectly acquainted with the art of smelting ores.* The scoriæ at Maresfield retain a far greater proportion of the metal than the cinders of other beds in the neighbourhood, and are, on that account, much more valuable for the purpose of road-making.

Since the discoveries at Maresfield, the writer has been furnished with further proofs of the fact that the Romans availed themselves of the iron of Sussex. From

* The greatest iron-works carried on by the Romans in this country were in Gloucestershire. So extensive were these works, and so imperfect the smelting, that in the sixteenth and following centuries the iron-masters, instead of digging for ore, resorted to the beds of scoriæ for their principal supply of the metal. – *Encycl. Britan. in voc.* "Iron."

the information of Mr. Robert Mercer, of Sedlescombe, it appears that many Roman coins have been found in a cinder-bed in that parish, on the land of Mr. Richard Smith. They have generally been greatly corroded, and some have evidently been burnt, as at Maresfield. All knowledge of the fact that iron-works had ever existed on the spot was lost until the discovery of the cinder-bed. Roman coins have also been met with upon the site of iron-works on the property of Mr. Hercules Sharpe, at Westfield, in the same neighbourhood. The writer is also assured that fragments of pottery, apparently Roman, were found, some years since, in a cinder-bed in the parish of Chiddingly.

In October, 1853, a first-brass coin of Faustina was found in a cinder-bank at Poundsley, in the parish of Framfield.

It is not improbable that the iron of Sussex was wrought in times even anterior to the conquest of this island by the Romans. Previously to the advent of Cæsar, the inhabitants of Britain must have made a considerable advance in the arts of civilization. To have subjugated the horse, and to have made such proficiency in many of the details of military science as the conqueror of Gaul found to his cost that they possessed, may well assert for them a degree of refinement quite at variance with the too generally received opinion, that they were mere savages and barbarians. If the use of iron be taken as the point at which pure barbarism ends and civilization begins, the ancient Britons had certainly passed that point, as the formidable scythes attached to the axles of their chariots sufficiently prove, to say nothing of the chariots themselves, which obviously were not made without the use of iron tools. Cæsar mentions that the currency of the people consisted partly of iron rings, adjusted to a certain weight (*utuntur aut ære aut annulis ferreis, ad certum pondus examinatis, pro nummo*), and, as he states, in the same breath, that their brass was imported (*ære utuntur importato*), it may reasonably be inferred that their iron was of home manufacture. And assuming that such was the case, the iron of our Wealds could hardly have escaped notice.

However great the error of Cæsar in asserting that Britain produced but little iron (*nascitur ibi in maritimis [regionibus] ferrum; sed ejus exigua est copia**), his allusion is useful as proving his knowledge of the fact that the island was not destitute of this invaluable mineral. And how he became acquainted with that fact, except from the information of the Britons themselves, it would be difficult to determine. It may be further remarked that the "maritime regions" referred to by him were, in all probability, the Wealds of Kent and Sussex.

The extent of the knowledge of the Romans with regard to the mineral productions of Britain in those after times when their power was well established here, is a subject worthy of a fuller investigation than has hitherto been made. Tacitus tells us that Britain produces "gold, silver, and other metals;" Pliny alludes to the smelting of iron in this province; and Solinus not only mentions the British iron, but specifies the agricultural and other implements fabricated from it in his time. The researches of modern geology and archæology have confirmed these statements.

Sir H. T. de la Beche has found gold in the quartz-formation of Gogofau, near Lampeter, in the vicinity of a traditional Roman settlement. Enormous mounds of broken and pounded quartz remain to attest the labour expended in the acquisition of the precious metal.† Silver is still found in Devonshire and Cornwall; and it was probably there that the silver mentioned by Tacitus was

* *De Bell. Gall.* lib. v, cap. 12.

† Vide 'Thoughts on Ancient Metallurgy,' &c., by Mr. John Phillips, F.R.S., G.S. *Yorkshire Philos. Soc.*, March, 1848.

procured. The tin of Cornwall (the *album plumbum* of Cæsar and Pliny) was known before the very name of Rome existed. Pigs of lead, stamped with Roman inscriptions, have frequently been found in Derbyshire and elsewhere. Four such pigs of British lead were found at Pulborough, in Sussex, 1824. Our copper, too, was well known to the Romans, and, as the writer believes, to the primitive Celtic race who preceded them. A due admixture of this metal with tin forms the imperishable bronze of which the instruments called "celts" are composed.

With regard to the seven or eight centuries which succeeded the departure of the Romans from Britain, history and archæology seem alike silent on the subject of the iron of the south. It can scarcely be doubted, however, that the Romanized Britons retained this most useful art of smelting and working iron, and that the Anglo-Saxons, after them, continued it upon the old sites. Further examinations of our cinder-beds may hereafter bring to light Romano-British and Saxon remains, and prove for those peoples what Maresfield has proved for the Romans. In the meantime, we are perhaps justified in assuming that when so valuable and necessary a manufacture had been once introduced, it would be retained so long as the three essentials for its perpetuation, the ore, the fuel, and the flux, continued in sufficient abundance of supply; in other words, that the iron-trade of the south was carried on uninterruptedly from Roman times till its extinction, in consequence of the failure of fuel, almost within our own recollection.

It is proper, however, to observe, that the trade, if in existence here at the date of Domesday Book, was very unimportant, since that invaluable record makes no mention of iron under the county of Sussex, though it does under those of Somerset, Hereford, Gloucester, Cheshire, and Lincoln.

Perhaps the earliest actual record of the iron-trade in the South is contained in the murage-grant made by Henry III. to the town of Lewes.* This grant, which is dated 1266, empowers the inhabitants to raise tolls for the repair of the town walls after the battle.† Every cart laden with iron from the neighbouring Weald, for sale, paid one penny toll, and every horse-load of iron, half that sum. From that period we have data, however slight, for the history of the manufacture.

In 1290, a payment was made for the iron work of the monument of Henry III. in Westminster Abbey, to Master Henry of Lewes.‡ Some years previously, the name of a Master Henry of Lewes, probably the same person, appears in connexion with iron work for the king's chamber.§

In the 7th year of Edward I., iron appears to have been smelted on St. Leonard's Forest, and the works were afterwards carried on by the Crown. In 1300, according to Stowe,‖ the ferrones or ironmongers of London made complaint to Elia Russell, mayor of London, that the smiths of the Wealds (*fabri de Waldis*) brought in iron for wheels, which were much shorter than they ought, according to custom, to be, to the great scandal and loss of the whole trade of ironmongers; and required a remedy, which was accordingly granted. From some incidental notices occur-

* A letter, written between the years 1233-1244 to Ralph, Bishop of Chichester, by his steward, Simon de Senliz, appears to militate against the existence of the iron-trade, at least in the western part of Sussex, at that period. It relates to an order from the bishop to one H. de Kynard for the purchase of iron (*x marcas de minuto ferro, si inveniri potest, sive autem, v marcas de grosso, et v marcas de minuto ferro*), to be procured in the neighbourhood of Gloucester, and thence conveyed to the *domus hospitis* at Winchester; an order which would scarcely have been necessary, if the iron-works which in the next century we find within a few miles of Chichester, had then been in operation. The letter is among the *Tower MSS.*, No. 677.

† Blaauw's *Barons' War.* Horsfield's *Lewes.* ‡ *Househ. Exp. Rot. Mis.* 56, 17.

§ Devon's *Issues of Exchcq.* ‖ *Survey of Lond.*

ring about this period, it appears that the iron manufactured near the Sussex coast was conveyed to London by water—a proof of the impassable state of the roads in those days.

In the 13th year of Edward II., Peter de Walsham, sheriff of Surrey and Sussex, by virtue of a precept from the king's exchequer, made a provision of horse-shoes, and nails of different sorts (*providencias de ferris equorumet clavis pro eisdem, diversimode fabrice*), for the expedition against the Scots. The number furnished on the occasion was 3,000 horse-shoes and 29,000 nails, and the expense of their purchase, from various places within the sheriff's jurisdiction, and their delivery in London, by the hands of John de Norton, clerk, was £14 13*s.* 10*d.**

Fig. 5.—Iron Monumental Slab, Burwash, Sussex.

The Nonæ return for the parish of Lynch in Western Sussex, proves the existence of the iron-trade there in 1342. It also affords an early instance of metals being subject to tithes: *Item, decima ferri ecclesiæ prædictæ valet per annum decem solidi.* The rector likewise received ten shillings for the tithe of iron ore.†

A curious specimen of the iron manufacture of the fourteenth century, and as far as the writer's own observation extends, the oldest existing article produced by our foundries, occurs in Burwash church. It is a cast-iron slab, with an ornamental cross, and an inscription in relief (Fig. 5). In the opinion of several eminent antiquaries, it may be regarded as unique for the style and period. The inscription is much injured by long exposure to the attrition of human feet. The letters are Longobardic, and the legend appears, on a careful examination, to be :—

ORATE P. ANNEMA JHONE COLINE (or COLINS.)

[Pray for the soul of Joan Collins.]

Of the identity of the individual thus commemorated, the writer has been unable to glean any particulars. In all probability, she was a member of the ancient Sussex family of Collins, subsequently seated at Socknersh, in the adjacent parish of Brightling, where, in common with many of the neighbouring gentry, they carried on the manufacture of iron, at a place still known as Socknersh Furnace.

The manufacture probably continued to increase during the fifteenth century, though that supposition is based more upon the flourishing state in which we find the trade in the early part of the sixteenth, than upon documentary evidence or archæological remains. A few relics of the latter portion of this period are, however, to be met with. Among these should probably be included a singular object preserved at the archiepiscopal palace of Mayfield, to which the writer's attention has kindly been drawn by Mr. Albert Way, who conjectures it to be a mustard-mill. (Fig. 6.) It is about 9½ inches square, with a hemispherical basin, at the bottom of which is a circular hole, 1 inch in diameter. It has four projections, like

* Wardrobe Account, Edward II. *Carlton Ride MSS.*

† Dalaway's *Rape of Chichester*, page 300.

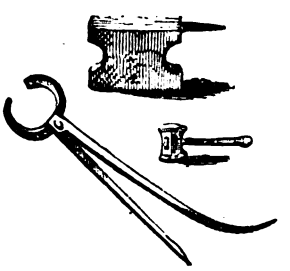
handles, by which it was probably worked.* To this date also belong a few of the andirons and chimney-backs which remain to attest the taste and skill of our local founders. The accompanying cut (Fig. 10) represents one of a pair of andirons from Eastbourne, now in the writer's possession. From the form of the shield, upon which the sacred monogram ihs appears, it probably belongs to the reign of Edward IV. Another specimen of the same type was formerly preserved at Netherfield Toll farmhouse, in the parish of Battel. At Michelham Priory are a pair of andirons of extremely interesting character, which are believed to have formerly occupied the curious antique chimney-piece in the apartment traditionally known as the "Prior's Chamber" (Fig. 11). They terminate in a human head, and the fashion of the head-dress fixes their date not later than the reign of Henry VII. (Fig. 12). The series of Sussex andirons ranges from the end of the fifteenth century to that of the seventeenth, or later, and during the whole of that period a regular decadence in the style of their devices is strikingly observable. In many of the old farmhouses, where, either from motives of economy, or from a predilection for old manners, the good wife, like the one celebrated by Horace,—

Fig. 6.

Fig. 10.

> Sacrum vetustis exstruat lignis focum,
> Lassi sub adventum viri,

these venerable and picturesque articles of furniture retain the post they have occupied for centuries. And could the uncouth heads, with which they are frequently decorated, open their mouths to reveal the forgotten past, how many a tale could they unfold of the scenes of homely felicity and of domestic wretchedness, which have transpired around them!† The chimney-backs are not generally of so ancient a date



Figs. 7, 8, and 9.

* The well-known objects preserved at Mayfield palace as genuine relics of St. Dunstan, seem to refer as much to the iron-trade, so famous of old in these parts, as to the alleged proficiency of the saint in the craft of a blacksmith. They consist (besides an old-fashioned sword) of an anvil, a pair of tongs, and a hammer (Figs. 7, 8, and 9). The anvil and tongs are of no great antiquity, but the hammer, with its solid iron handle, looks like a genuine relic of medieval times. The massive hand-rail of the great stone staircase is another interesting specimen of the local manufacture. The writer may add that it was probably here, upon the archiepiscopal manor, that the iron copings of Rochester bridge, presented to that city early in the sixteenth century by the primate Warham, were manufactured.

† The writer employs the word *andiron* as a term generally known. The Promptorium Parvulorum has "awnderne, awndyryn, awndyrn," vide *Way's Prompt. Parv.* Camd. Soc. *in voc.* The etymology is uncertain. In Sussex, the word more generally employed is either *brand-dogs*, or *brand-irons*, the latter from the Anglo-Saxon "brandisen," or "brand-iren;" an interesting example of the local retention of an ancient word which has grown out of general use.

as the andirons, though one or two specimens may probably be referred to the fifteenth century. Others of a later style have some details belonging to this period, proving that the founders preserved the models which had been employed by their predecessors. Thus a "back" at Buxted (belonging to Mr. T. Wickens), which bears the badge and initials of Queen Elizabeth, is decorated with a band composed of grapes and vine-leaves, in a running pattern, belonging to a considerably earlier date; and the writer has met with similar instances elsewhere.

The sacred monogram ihs occurs on the shield, which is almost uniformly introduced into the design of the andirons, up to the time of the Reformation, when it is generally superseded by a coat of arms, or some other device. Fig. 13 is one of a pair belonging to Mr. Wickens, of Buxted: it was probably cast in the early part of the sixteenth century. At the Sergisson's Arms public-house, Hayward's Heath, is a very large pair, ornamented in a rather singular manner. The shield, which occupies the ordinary position at the insertion of the legs, bears

Fig. 11.

Fig. 12.

the arms of France, a favourite device on our iron-works; and above it, on another shield attached to the pillar or stem of the andiron, is the legend ȝ holy on (Fig. 14). The letters R.F. above, and the G.B.C. below, may be the initials of the founder, and of the person for whom they were made, with, perhaps, that of his place of residence. With respect to the meaning of the legend, there is much scope for conjecture: perhaps it should be read "Jesus Holy One." If this be a correct interpretation, it affords another instance of the vulgar misapprehension of the meaning of the Greek IHΣ, the very ancient contraction of Ἰησοῦς, corrupted during the middle ages to I.H.S. or ihs, and interpreted to signify *Jesus, hominum Salvator*. Sometimes the Σ was taken to be a c, and the ihc was read *Jesus, hominum Consolator*. These misapprehensions originated with the clergy, who were, in those days, generally unacquainted with Greek; but the vulgar, who were equally unlearned in Latin, had their reading also, and made I.H.S. stand for "Jesus Holy Saviour," which is still retained as its meaning by

the illiterate in Sussex. When the monogram took the form of ihc, the last letter might be easily mistaken for an o, and in this way, the writer is disposed to believe, the founder made it the initial of "one," and thus developed a new theory upon this *diu vexata quæstio* by producing the "Jesus Holy One," upon this andiron. The writer must add, however, a suggestion made since the original publication of this memoir, namely, that the legend is simply "I holp" or "help on," alluding to the usefulness of an andiron.

Fig. 13.

Fig. 14.

To return to the history of the manufacture. There is little doubt that ordnance was made in this county in the fifteenth century. It is believed that some of the old banded guns of wrought iron preserved in the Tower of London, and elsewhere, and dating so far back as the reign of Henry VI., were of Sussex

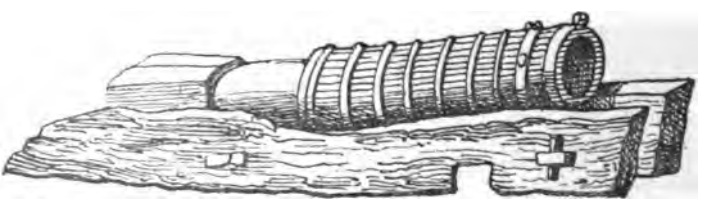


Fig. 15.—Banded Cannon at Eridge Green.

manufacture. In the tenth volume of the *Archæologia** is an engraving (Fig. 15) from a drawing by Mr. James Lambert, jun., of a mortar, formerly at Eridge Green, in the parish of Frant, and the account given of it is as follows:

"It has always been understood that this mortar was the first that was made in England. . . . . [It] now lies at Eridge Green, and has served for many years for the amusement of the people on a holiday or fair-day, when they collect

* June, 1790, page 472.

money to buy gunpowder to throw the shell to a hill about a mile distant. The weight of the shell sinks it so deep into the earth, that it costs no little pains to dig it out after each discharge, which is repeated as long as the money lasts. 'The chamber of the gun is cast-iron, the other part, as is evident, wrought."

From the engraving, the chamber appears to have been polygonal, and the tube to have consisted of many small bars or rods, bound together by nine hoops. This was the original method of constructing these tremendous engines of war.* A French writer, St. Remy, says, *Qu'elles ne consistoient qu'en de fortes tables de fer qu'on disposoit à peu près cylindriquement, les serront avec de cercles de fer.*† There can be no reasonable doubt that the Eridge gun was of Sussex manufacture; and it is equally probable that many, if not most, of the pieces employed by our armies in the continental wars of the fourteenth and fifteenth centuries were the productions of the southern iron-works.

These hooped guns were at length superseded by cannons cast in an entire piece, and bored, as at the present day. The invention of gun-founding is ascribed to the French, who appear to have used cast pieces many years before the introduction of the art into this country. The first iron cannons cast in England were manufactured at Buxted, in Sussex, by Ralph Hoge or Hogge, in 1543 (the 35th year of Henry VIII.).‡ This founder employed, as his assistant, Peter Baude, a Frenchman, whom he had probably brought over to teach him the improved method; and Peter Van Collet, a Flemish gunsmith, about the same time, "devised and cast mortar pieces from 11 to 19 inches bore; for the use whereof they caused to be made bombs, or certain hollow shot, of cast-iron, to be stuffed with fireworks, &c. And after the king's return from Bullen, the said Peter Bawde, by himself, in the 1st year of Edward VI., made ordnance of cast iron, of divers sorts, as *fawconets, fawcons minions, sakers*, and other pieces." It seems that Baude's connection with Hogge was of no long continuance; for we find that "John Johnson, covenant servant to the said P. Bawd, succeeded and exceeded his master in this his art of casting ordnance, making them cleaner and to better perfection. And his son, Thomas Johnson, a special workman, in and before the year 1595, made 42 cast pieces of great ordnance of iron, for the Earl of Cumberland, weighing 6,000 lbs., or three tons a-piece."§ Whether Sussex was the scene of these operations, however, does not appear.

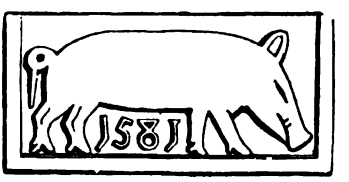


Fig. 16.

The family of Hogge resided at a place near Buxted Church, called, from their rebus or "name-device," (Fig. 16), still existing over the front door, the Hog-house, and now the property of Colonel Harcourt. They were connected with the business of gun-founding for at least three generations. About the 16th year of Elizabeth (1574), Bryan Hogg held the office of Clerk of the Deliveries, with a fee of £18 5*s.* per annum; and his successor was George Hogg. ‖

* For a very able and interesting account of ancient ordnance, see a paper by Mr. C. D. Archibald, F.R.A.S., &c., in *Archæologia* vol. xxviii., page 373. Our historians generally assert that cannon were first employed at the battle of Crecy, in 1346: but Mr. Archibald adduces strong reasons for the belief that they had been previously used Edward III. in his expedition against the Scots in 1327.

† *Artillerie* l, viii., quoted in *Archæologia*, vol. xxviii., page 380.

‡ *Holinshed*, ii., 960.—"Bucksteed." § *Hayley's MSS.*, British Museum.

‖ Type's *Stowe's London*, vol. i., page 107.

The name of Hogge or Hoggé seems to have been confounded with that of Huggett; and there is a place on the confines of Buxted and Mayfield, called Huggett's Furnace, where, according to tradition, the first iron ordnance was cast. The traditionary distich that

Master Huggett and his man John,
They did cast the first Gun-non,

is firmly believed in the locality.*

But to return: Peter Baude, the associate of Ralph Hogge, did not limit his exertions to iron pieces. Some fine specimens of brass or "gun-metal" ordnance from his hand are still extant. One John Owen, it seems, had, at a somewhat earlier date (1521, Stowe—1535, Camden), made great brass ordnance, as cannons and culverines.† Whether this man did not succeed, or whether he died previously to 1543, is not mentioned, but at that date Baude was busily engaged in the fabrication of brass guns, two of which still remain in the Tower of London collection. One of these is an elegant octagonal piece, adorned with the royal arms, the fleur-de-lis, and the king's initial "H," surmounted by a crown, with the date 1543, and the initial of the founder's name, "B," over the touch-hole.‡ The other is a very fine specimen of the "triple-chamber piece," which was unfortunately broken into several pieces, and otherwise mutilated, by the fire of 1841. It is 6½ feet in length, and has three bores, 2¼ inches in diameter. Its upper surface is ornamented with the Tudor badge of the rose and crown, the latter supported by cupids; and with the kind of arabesque device prevalent at this period. Beneath the badge is the legend—

HENRICVS OCTAVVS
DEI GRACIA ANGLIE ET
FRANCIE REX FIDEI
DEFENSOR DNS HIBERIE.

near the muzzle—

POVR DEFENDRE;

and at the opposite end—

PETRVS . BAVDE . GALLVS . OPERIS . ARTIFEX.

Among the Battel Abbey Deeds§ is a document called "Westalle's Book of Pannyngrydge, A° regni Regis Hen. VIII., xxxviij" (1546). It is the account-book of some iron-master, and exhibits his expenditure in carrying on an extensive trade during the year indicated. Among the items are payments made to the wood-cutters for "coards" of wood, at 3*d.* per coard. The "collears," or charcoal-burners, were paid in wood, and money for coals, at the rate of 22*d.* per load. There are also charges for the carriage of coals out of Pannyngrydge, Olyver's Wood, and Asyldey, at 4*d.* and 6*d.* a load; and for the "moyne digged out of Pannyngrydge." "Moyne" was, of course, the iron ore, still called "iron-mine," and giving name to many spots, as "Mine-pit Field," "Mine-pit Shaw," &c. The price of digging was 7*d.* per load; and many payments to "Black

* As an instance of the tenacity with which families sometimes adhere to a particular vocation, it may be mentioned that many persons of the name of Huggett still carry on the trade of blacksmiths in East Sussex.

† "There are now at Woolwich several guns lately recovered from the wreck of the 'Mary Rose,' which was sunk at Spithead in 1545; and among them two large brass cannons, the one a 68, the other a 24 pounder, which, in beauty of design and workmanship, are equal to anything that could be produced in the present day." *Archæologia*, (ut supra).

‡ Hewitt's *History of the Tower*, 12mo, 1841.

§ Formerly in the possession of the Webster family, now in that of Sir Thomas Phillipps, of Middle Hill; a most valuable collection of Sussex MSS., bound in 97 folio volumes.

Jack," and others, occur in these accounts. Several sums are paid to Warnet, the founder, and to Anthony, the "filler." One entry shows the locality where these operations were carried on:

"For carying of lodes of sand from Pannyngrydge unto my forge at Robertsbridge, at xvjd. the lode."

There are further sums paid to Mr. Chanceller for the farm of his woods at Pannyngrydge, and to the parson of Penherst for the farm of the *phurner* (furnace) pond there, and for tithe. Also for the hewing and felling of timber, "for drawing of timbre to the saw-stage," &c. The accounts close with an entry of v*s.* v*d.* paid "for a wrytte and a warrant for Jackson, the carpenter." *

The manufacture of heavy ordnance gave a great impulse to the iron-trade. Many foreigners were brought over to carry on the works. This perhaps may account for the number of Frenchmen and Germans whose names appear in our parish registers about the middle of the sixteenth century. New works were established, and ultimately almost every landed proprietor in the districts where the ore was found became an iron-master. Among the persons engaged in the trade at this period, was Richard Woodman, one of the ten Protestant martyrs burnt at Lewes in 1557. He was a native of Buxted, where he probably learnt the business. At the time of his apprehension, at the beginning of Queen Mary's reign, he resided at Warbleton, and carried on an extensive trade. In one of his examinations before the Bishop of Winchester, he says, "Let me go home, I pray you, to my wife and children, to see them kept, and other poore folke that I would set aworke, by the helpe of God. I have set aworke a hundredth persons, ere this, all the yeare together." † Several Sussex families, enriched by the iron manufacture, assumed the rank of gentry about this time.

This rapid growth of the trade in the Wealds of Sussex and Kent was viewed with disfavour by many. Archbishop Parker, writing to Queen Elizabeth in 1570, says: "Sir Richard Sackville intends, as I was credibly informed, in this wood [Longbeech Wood, in Westwell, Kent] to erect up certain iron-mills, which plague, if it shall come into the country, I fear it will breed much grudge and desolation. ‡

It is curious to find about this time the ancestors of many of the existing representatives of what is called the "landed interest" busily employed in the iron-trade—and to trace their augmentation of wealth by this means. In the days of Elizabeth, the Ashburnhams, the Pelhams, the Montagues, the Nevilles, the Sidneys, the Sackvilles, the Dacres, the Stanleys, the Finches, the Gages, and even the Percys and the Howards, did not disdain such lucre, but pursued it to the destruction of old ancestral oak and beech, and with all the apparent ardour of Birmingham and Wolverhampton men of these times. We may add after these, the Culpepers, the Dykes, the Darrels, the Apsleys, the Coverts, the Morleys, the Shirleys, the Burrells, the Greshams, the Bullens (kinsmen of royalty), the Gratwickes, the Bakers, and the Fullers. Concerning the last-mentioned, there is a foolish tradition that the first of the name and family in Sussex gained his wealth by hawking nails about the county on the backs of donkeys! This is absurd; but at the same time it is generally understood that the family were greatly enriched by the manufacture—a fact which is indeed frankly avowed in their singular motto: *Carbone et forcipibus.*

About 1572, much ordnance was exported, in consequence of the Lord Admiral having granted a license for that purpose to Sir Thomas Leighton, who had made use of one Garret Smith to obtain it of the admiral, and who was, in return for his

* Vide Thorpe's *Descriptive Catalogue of the Muniments of Battel Abbey*, 8vo, London, 1835. † John Foxe, *Acts and Mon.*, edition 1570, page 2192.

‡ Strype's *Life of Archbishop Parker*, page 315.

intervention, to enjoy the deputyship, with a fourth part of the profits;* "but the merchants of London, knowing how this might furnish the enemies' ships to obstruct their trade, and bring other great damages upon the queen and her subjects, petitioned her, in a great body, to withdraw this license." The petition was not presented ("whether it were shuffled off by some about the queen"); however, they petitioned again, and in Sept., 1572, a proclamation strictly restrained all transport of iron and brass ordnance, and forbade the owners of all iron-works, furnaces, or forges, to make any kind of ordnance larger than a minion.

The following year, a declaration was made to the council, of the great consumption of oaken wood in Sussex, Surrey, and Kent by the iron mills and furnaces."†

In the State Paper Office, Jan. 1574 (No. 15), there is a petition from Ralphe Hogge, "manufacturer of guns and shot for the Ordnance office," to the council, complaining of the infringement of the patent granted by the queen, for the sole exportation of ordnance; whereupon a return was procured on February 15th following (No. 18), giving a list of the owners of iron-works in the three counties. The chief men were summoned before the council, and from the others bonds were taken, under a penalty of £2,000 not to found or sell ordnance without license from the queen.

In defiance of these measures, however, the surreptitious exportation of Sussex cannon went on for some years longer. In 1587, the Earl of Warwick, master of the ordnance, despatched "a gentlemen of his, one Mr. Blincoe," into Sussex, to summon all the gunfounders of the county up to London, to understand his pleasure respecting their further continuance of the manufacture. "Henry Nevel, and the rest of that occupation," obeyed the summons, and the matter was referred to the arrangement of Mr. Hockenal, the deputy-master of the ordnance, and Mr. Blincoe. The result was, that a fixed quantity of cannon should be cast annually, for the necessary provision of our own navigation; a certain proportion being allowed to each founder. It was also stipulated that no ordnance should be sold except in the city, and not even there but to such merchants "as my lord or his deputy should name."‡

The bonds into which the iron-masters entered on this occasion seem to have been little regarded by them; for on August 8th, 1589, Thomas Lord Buckhurst wrote a letter to the justices of Lewes Rape, complaining of their neglect. "Their lordshypps doe see the little regard the owners of furnaces and the makers of these peeces have of their bondes, and how yt importeth the state that the enemy of her majesty should not be furnished oute of the lande with ordnance to annoye us." The lord-treasurer goes on to direct the magistrates to enforce the provisions of the master of the ordnance. Another letter, from the same officer to the justices of the three eastern rapes, dated October 6th, 1590, directs them as to "straighter restraint of making shott and ordnance," and to take bonds of £1,000 each of every furnace-owner and farmer; and also to forward their bonds, and a list of their names, to him with all convenient speed.§

To return to the archæology of our subject: the eastern division of Sussex still abounds with specimens of the workmanship of the sixteenth century, particularly andirons and chimney-backs. Some of these are decorated with fanciful devices, and others with armorial bearings. The royal arms and badges are of the most usual occurrence. At Riverhall, in the parish of Wadhurst, is one of the former class (Fig 17). It probably belongs to the early part of this century. Besides the royal arms—France and England quarterly, with supporters—and the Tudor badge of

* Strype's *Stowe*, vol. ii., page 293. † State Paper Office, 1573 (No. 96).

‡ Strype's *Stowe*, vol. i., page 108.

§ These letters are printed in full in Horsfield's *Lewes*, vol. i., page 192.

the rose and crown four times repeated, it exhibits a crowned shield, charged with the initials E. H., probably those of the original proprietor, and ten human figures, with monkey or doglike heads (perhaps intended for "mummers"), and two

Fig. 17.—Chimney Back at Riverhall.

swords. The back is of large dimensions, and the figures which make up its fanciful device were evidently impressed separately in the sand from the same models. According to tradition, this curious article was cast at a furnace on the estate. The writer may also mention two other "backs" of this century. The first, much mutilated, has the royal arms, supported by a dragon and a greyhound, with the initials E. R., probably for Edward VI. The side ornaments are a dragon's head, the *rose-en-soleil* and the double rose. The orthography of the royal motto, DV ET MOVN DR—, and of that of the garter, HONY SOYT QVE MAL Y PAVNC, bespeak it the work of an unlettered artisan, and the inscription beneath the shield exhibits the name of the founder, In Sussex—By John Haws (or Hawo—, perhaps intended for Haworth, but incomplete for want of room). Another "back" has the badge and supporters of Queen Elizabeth, and the legend—

THOMAS VNSTEAD, ISFILD, AND DINIS
HIS WIF, ANO DOMINO, 1582.

Fig. 18.—Andiron at Old Land Farm, Maresfield.

A third specimen, in the possession of Captain Richardson, of Sutton Hurst, has the badge and supporters of Queen Elizabeth, and the legend: THIS . IS . FOR . IAMES . HIDE . AND . JON . HIS . MIF . 1582 (Fig. 19).

A very singular type of chimney-back is found in some old houses in Surrey, and there is a specimen in the Sussex Archæological Society's Museum at Lewes. It is of the ordinary shape, and has the common ornaments of the period, and this inscription:—

HER : LIETH : ANE : EORST
R : DAVGHTER : AND :
HEYR : TO : THOMAS
GAYNSFORD : ESQVIER
DECEASED : XVIII : OF
IANVARI : 1591 : LEAVING
BEHIND : HER : II SONES
AND : V : DAVGHTERS.

In Crowhurst Church, Surrey, an iron slab bearing this inscription with some accessories, covers the remains of the lady whose memory it records. It is evidently cast from the same mould as the "backs;" but the reason for thus publishing the lady's heirship to the ancient line of Gaynsford on the hearths of strangers is not easily to be adduced.

Fig. 19.—Chimney Back at Sutton Hurst.

Many of the andirons of this period have the arms of the families for whom they were cast embossed upon their shields. The accompanying example (Fig. 20), from a sketch by Mr. C. Howard Ellis, is in the possession of Mr. Marchant, of Hurstperpoint. It was brought from Slaugham Place, the seat of the Coverts, but bears the arms of the Kentish family of Cromer. It will be observed that this specimen has nothing of the Gothic or medieval character of the earlier examples. The founders uniformly imitated the architectural details of their respective eras.

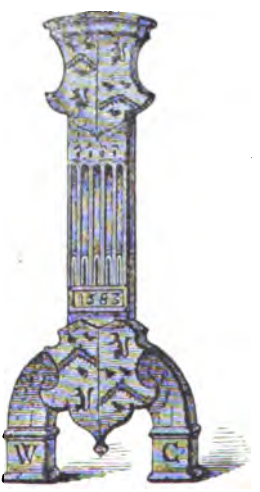


Fig. 20.

The andiron next shown (Fig. 21), from a sketch by Mr. William Figg, is at Rowfant, in the parish of Worth. The date is 1591. The arms are those of the family of Ashburnham, and the ornament upon the pillar is a rude attempt at their punning crest—an ash-tree springing from a ducal coronet. This is doubtless a production of the Ashburnham furnace. The other (Fig. 22) is a mutilated andiron at the Crow and Gate public-house, near Crowborough, and is ornamented with emblems of the smith or farrier's occupation displayed upon the shield.

The great extent which the manufacture had now reached threatened an evil which had to be warded off by legislative enactments—the writer means the annihilation of timber in the Weald. Up to a certain period the destruction of trees and underwood had been beneficial in clearing the

for agricultural purposes;* but so early as the reign of Henry VIII. (1543), became necessary to enact—that no wood shall be converted into pasture—in cutting coppice-woods at twenty-four years' growth, or under, there shall left standing and unfelled, for every acre, twelve "standils" or "storers" of oak, a default of so many, then of elm, ash, asp, or beech—and that if the coppice under fourteen years' growth, it shall be inclosed from cattle for six years; provided always, &c., that this act do not extend or be prejudicial to any of lords or owners of the woods, underwoods, or woodlands growing or being within any of the towns, parishes, or places commonly called or known to be within the Wilds of the counties of Kent, Surrey, and Sussex, other than to the common woods growing and being within any of the said Wilds," &c.†

A series of enactments of similar character succeeded. The act of the 1st year of Elizabeth, cap. 15, provides that no person shall convert into coal or other fuel for the making of iron, "any timber-trees of oak, beech, or ash of the breadth of one

Fig. 21.

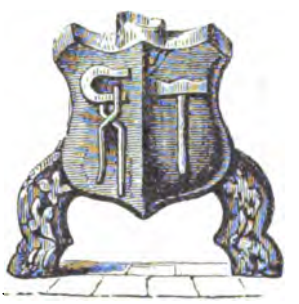


Fig. 22.

foot square at the stub," within fourteen miles of the sea, or the rivers Thames, Severn, &c., or any other navigable river. The county of Sussex, the Weild of Kent, and the parishes of Charlewood, Newdigate, and Leigh, in the Weild of Surrey, were however excepted from the operation of this act.

The act of the 23rd year of Elizabeth, cap. 5 (1581), declares that "by reason of the late erection of sundry iron-mills in divers places," near London, and "not far distant from the Downs and sea-coasts of Sussex," decay of timber hath ensued; and forbids, therefore, the converting "to coal, or other fewel, for the making of iron-metal in any iron-mill, furnace, or hammer," any wood within twenty-two miles of London, or within four miles of the foot of the hills called the Downs, betwixt Arundel and Pemsey, or within four miles of the towns of Winchelsey and Rye, or within two miles of the town of Pemsey, or within three miles of the town of

* In illustration of this remark it may be mentioned that in the 30th year of Edward III., one Robert de Dole died possessed, *inter alia*, of 60 acres of land at Billingshurst, which was declared to be worth only 10*s.* per annum, or 2*d.* per acre, because the land was barren and lay in the Weald (*et jacet in Wealdâ*), and was of no value to sow, on account of the quantity of wood (*propter magnitudinem bosci*).—*Inq. post Mort.*

† Statutes of the Realm, 35 Hen. VIII., cap. 17. This act was passed for seven years, but made perpetual by 13 Eliz. c. 25.

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ors of the dialogue, replies: "It
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were in Sussex neere 140 hammers
oining three or four glasse-houses ;†
in every 24 houres, two, three, or
unteth to an infinit quantitie, as you
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bred amongst woods are naturally more
countries ! ‡

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peaking of Sussex, says: "Full of iron-
making and founding thereof, there be
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, they might be of power sufficient to
e iron, resound all over the places ad-
'a (edition 1722) gives a more graphic
is turned into ponds and pools for the
.ting with hammers upon the iron, fill
lay, with continual noise."
iron here wrought is not in every place
than the Spanish iron; whether it be
Howbeit commodious enough to iron-
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vorks. The scoriæ found there differ con-
nary iron-works, having a more vitreous
ne peculiarity in the flux.
.ces," *Suss. Arch. Coll.* vol. ii., page 60.

Hastings, under a penalty of forty shillings for every load of wood so employed. "Provided always, that this act shall not extend to any woods growing or to grow in the Weilds of Surrey, Sussex, and Kent," if eighteen miles from London, and eight from the Thames. It also forbids the erection of any new iron-works within twenty-two miles of London, or four miles of the Downs, or of the towns of Pemsey, Winchelsey, Hastings, and Rye, upon pain of £10. The woods of Christopher Darrell, gentleman, at Newdigate, in Surrey, are exempted from the force of this enactment, on the ground of their having been preserved and coppiced for the especial use of his iron-works in those parts. The act of the 27th year of Elizabeth, cap. 19 (1585), rehearses, "Whereas by the over great negligence or number of iron-works which have been and yet are in the Weilds of Sussex, Surrey, and Kent, it is thought that the great plenty of timber which hath grown in those parts hath been greatly decayed and spoiled, and will in short time be utterly consumed and wasted, if some convenient remedy be not timely provided," and therefore forbids the erection of any manner of iron-mill, furnace, finary, or blomary,* for the making or working of any manner of iron or iron-metal," except upon ancient sites.

The highways of Sussex were, at that time, as well as at a much more recent date, proverbially bad, wherefore the act above cited enjoins upon all persons carrying charcoal, mines, and iron, between October and May, "for every six loads of coals or mine, or for every ton of iron, to carry one usual cart-load of cinder, gravel, stone, sand, or chalk, meet for the repairing or amending of the said highways."

In spite of the enactments for the preservation of wood, the waste still continued. John Norden, in his *Surveyor's Dialogue*,† after referring to the statute of the 35th year of Henry VIII., says, "but mee thinks this statute is deluded and the meaning abused; for I have seene in many places at the fals, where indeed they leave the number of standils and more; but in stead they cut downe them that were preserved before, and at the next fall them that were left to answer the statute, and yong left againe in their steads; so that their can be no increase of timber-trees." "But," he adds, "some countries are yet well stored, and for the abundance of timber and wood were excepted in the statute, as the Welds of Kent, Sussex, and Surry, which were all anciently comprehended under the name of Holmesdale, . . . and yet he that well observes it, and hath known the Welds of Sussex, Surry, and Kent, the grand nursery of those kind of trees, especially oake and beech, shal find such an alteration within lesse then 30 yeres, as may well strike a feare, lest few yeeres more, as pestilent as the former, will leave fewe good trees standing in those Welds. Such a heate issueth out of the many forges and furnaces for the making of iron, and out of the glasse-kilnes, as hath devoured many famous woods within the Welds; as about Burningfold, Lopwood Greene (Loxwood), the Minns, Kirdford, Petworth Parkes, Ebernowe, Wassals, Rusper, Balcombe, Dallington, the Dyker, and some forests, and other places infinite.

Tantumævi longinqua valet mutare vetustas.

The force of time and men's inclination make greater changes in mightie things. But the croppe of this commodious fruit, which nature itself doth sowe, being

* For the meaning of these expressions see, Ray's account of the manufacture, in a subsequent page. The writer may add here, that the phrase *bloma ferri* occurs several times in Domesday Book. "*Bloma*," a Saxon word, is defined by Bosworth as "metal, a mass, lump." "Isenes bloma, *massa ferri*, bloom of iron." (*First Report of Record Commiss.* page 416.)

† London, 1607, page 213.

thus reaped and cut downe by the sickle of time, hath been in some plentiful places, in regard of the superfluous abundance, rather held a hurtfull weed than a profitable fruit, and therefore the wasting of it held providence, to the end that corne, a more profitable increase, might be brought in, in stead of it. . . . But it is to be feared that posterities will find want, where now they think is too much."

To this the Baylie, one of the interlocutors of the dialogue, replies: "It is no mervaile, if Sussex, and other places you speak off, be deprived of this benefit; for I have heard, there are or lately were in Sussex neere 140 hammers and furnaces for iron,* and in it and Surry adjoining three or four glasse-houses;† the hammers and furnaces spend, each of them in every 24 houres, two, three, or foure loades of charcoale, which in a yeere amounteth to an infinit quantitie, as you can better account by your arethmetique, then I."

The surveyor rejoins: "That which you say is true; but they worke not all the yeere, for many of them lacke water in the summer to blowe their bellows. And to say truth, the consuming of much of these in the Weld is no such great prejudice to the weale publike, as is the overthrow of wood and timber in places where there is no great quantitie, for I have observed that the clensing of many of these Weld grounds hath redounded rather to the benefit then to the hurt of the country; for where woods did grow in superfluous abundance there was lacke of pasture for kine, and arable land for corne, without which a country, or country farme, cannot stand, or be releeved but by neighbour helpes, as the Downes have their wood from the Weld. Beside, people bred amongst woods are naturally more stubburn and uncivil, then in the champion countries!‡

The quietness of our beautiful Weald at the present day offers a striking contrast to the ceaseless activity and bustle which characterised it in its iron age, the days of the Tudors and Stuarts. Camden, speaking of Sussex, says: "Full of iron-mines it is in sundry places, where, for the making and founding thereof, there be furnaces on every side, and a huge deal of wood is yearly burnt; to which purpose divers brooks in many places are brought to run in one channel, and sundry meadows turned into pools and waters, that they might be of power sufficient to drive hammer-mills, which beating upon the iron, resound all over the places adjoining." A later edition of the *Britannia* (edition 1722) gives a more graphic account: "A great deal of meadow ground is turned into ponds and pools for the driving of mills by the flashes, which, beating with hammers upon the iron, fill the neighbourhood round about, night and day, with continual noise."

"Yet," adds our great antiquary, "the iron here wrought is not in every place of like goodness; but generally more brittle than the Spanish iron; whether it be by nature, or tincture and temper thereof. Howbeit commodious enough to iron-maisters, who cast much great ordnance thereof, and other things to their no small gain. Now whether it be as gainful and profitable to the commonwealth may be doubted; but the age ensuing will be better able to tell you."

* It is a somewhat singular coincidence that the number of corn-mills in Sussex, at the time of the Domesday survey (finished in 1086), was 148; and that of iron-mills, about five centuries later, 140. A great proportion of the latter probably occupied the sites of the former, which the introduction of windmills had caused to be deserted.

† The dearth of information regarding the glass manufacture in the south is much to be regretted. The Rev. E. Turner conjectures that one of the "glasse-houses" was at Maresfield, near the site of the Roman iron-works. The scoriæ found there differ considerably in character from those of the ordinary iron-works, having a more vitreous appearance. This however may result from some peculiarity in the flux.

‡ Vide "Certificate concerning Sussex Justices," *Suss. Arch. Coll.* vol. ii., page 60.

That some of the iron wrought here was of the first quality there can be no doubt. The Ashburnham iron, particularly, excelled in the quality of toughness, and the writer has been assured by smiths who have used it, that it was in nowise inferior to the Swedish metal, generally accounted the best in the world. Camden's remark respecting the superior texture of Spanish iron is scarcely reconcilable with the statement of Fuller: "It is almost incredible how many great guns are made of the iron in this county. Count Gondomer [the Spanish ambassador] well knew their goodness, when of King James he so often begged the boon to transport them."*

Although the English monarch very properly declined the solicitation of Gondomer, one of his subjects, Sir Anthony Sherley, is known to have presented the King of Spain with a hundred pieces of cannon. "How he came by them," says Captain Alexander Hepburn, "I know not; but this is true by God in heaven."† There is, however, little mystery as to the source whence this artillery was derived; for Sir Anthony's father, Sir Thomas Sherley of Wiston, was an extensive manufacturer of Sussex iron.

This brings us to the seventeenth century, a period in which the Sussex iron trade reached its greatest extent. The number of mills and furnaces had increased yearly, in spite of the statutes limiting their extension, and the waste of timber was again brought before the notice of government. In 1636, Charles I. granted a commission to Sir David Cuningham, Bart., Christopher Lewknor, Esq., and others, for its better preservation. "Whereas several offences have been heretofore and still are done and committed by . . . maisters, owners, and occupiers of iron-works, forges, furnaces, or hammers, for melting and making of iron, by felling, cutting, and converting of timmer trees (*sic*) and woods into coals for the melting and making of the said iron, &c. . . . and by felling the said trees and underwood at unseasonable parts of year, whereby the bark thereof hath been lost; and by ingrossing of iron and iron-works, &c., and thereby inhancing the prices of iron, &c., contrary to our laws and proclamations made for the preservation of timber and woods." It appears that there were several suits touching these offences pending in the court of Star Chamber, and the duty imposed on the commissioners was, "to treat and compound with" the offenders, and to levy, for the king's use, such sums as they should see fit. The commission was dated at Canbury, August 19th, 1636.‡ On October 14th following, an office, "to be for ever continued," was erected for the better management of the iron-trade, and the king appointed "John Cupper and Grimbald Pauncefoote, gentlemen, surveyors of all iron-works, and of all woods to be used and employed thereat, and for the surveying and marking of iron with divers stamps or marks distinguishing the several kinds." On July 29th, 1637, by an order in council these regulations were put in force, and very stringent methods were adopted for the rectification of the evils complained of. §

The founders of this century did not limit their operations to iron. The writer is not aware that bronze cannon continued to be made, but the casting of brass was extensively carried on. Bell-founding was successfully practised. The churchwardens' accounts at Eastbourne show that a new peal for their church was cast at Chiddingly. The following extracts are interesting:

* Fuller's *Worthies*, Sussex, vol. iii., page 241, edition 1840.

† Shirley's *Three Brothers*. Roxburghe Club.

‡ *Rymer*, xx., 68.

§ *Rymer*, xx., 161. Both the foregoing instruments were revoked by a proclamation, "given at York" in 1639, *Rymer*, xx., 340.

DISBURSEMENTS, A.D. 1651.

	£	s.	d.
"Item, to the bell-ffounder, John Lulham, for castinge the bells by composition	7	0	0
"Item, to John Lulham, for addition of belmettall, and for six daies labour about the bells, besides the remaininge mettall after the castinge	2	5	0
"Item, for carrying the bells and belmettall to Chittingly, and from Chittingly, June the 5th and July the 8th	1	10	0
"Item, to Mr. ffrench [of Chiddingly] and the fforger, for the treble clapper	0	8	0
"Item, to J. L. for his dyet and horsemeate, 3 daies	0	3	0"

There are many other entries relating to expenses about the bells.

"Item, to Richard Miller, of Chittingly, for two brasse pots, weighing 36 li. at 5*d.* the pound ... ... 15*s.*" *

The third bell at Chiddingly bears the inscription—"ROBERT TAPSELL MADE ME," and the name of this person appears in the parish register as a resident there.

In the register of Berwick is this entry: "Nov., 1690. The little bell was new cast at Alfriston."

At Ripe, there is a tradition that some of the bells of that church were cast on the waste close to the churchyard. Those of Hailsham Church were founded at a spot near the town still called Bell-bank.

Many of the culinary articles called "skillets" were also manufactured between the years 1625 and 1670. Some of them bear the name of Rummins. Tradition states that a family of this name, natives of Lamberhurst, travelled about the country with these articles, which they cast at the various foundries of the district, as occasion required.†

Steel was also manufactured in several places; particularly at Warbleton, where there is a place still called the Steel-forge Land, and at Robertsbridge. In 1609, John Hawes held the site of the abbey of Robertsbridge with the buildings, &c., "lying between two fresh-water rivers, abutting at the great stone bridge at the Forge Pond," and including various buildings for the steel-makers, among which were eight steel forges; "also one great gate-house, called the West Gate, built of lime and stone, and used in part as a dove-house, and in part for the steel-makers; also a great gate called the East Gate, employed as a store-house for iron, with a house attached to it for James Lamye, the hammer-man."

Drayton in his *Polyolbion*, published in the year 1612, makes the Sussex woods complain of the injury done them by the iron-works, in the following passage, which may be regarded as one of the finest in that noble, though singular and laborious, topographical poem:—

> "These forests, as I say, the daughters of the Weald,
> (That in their heavy breasts had long their griefs concealed,)
> Foreseeing their decay each hour so fast come on,
> Under the axe's stroke, fetch'd many a grievous groan,
> When as the anvil's weight, and hammer's dreadful sound,
> Even rent the hollow woods and shook the queachy ground;
> So that the trembling nymphs oppress'd through ghastly fear,
> Ran madding to the Downs with loose dishevell'd hair.
> The Sylvans that about the neighbouring woods did dwell,
> Both in the tufty frith and in the mossy fell,

* Ex orig. olim penes Lt.-Col. J. H. Willard.

† Ex inf. Rev. E. Turner.

Forsook their gloomy bowers, and wander'd far abroad,
Expell'd their quiet seats and place of their abode,
When labouring carts they saw to hold their daily trade,
Where they in summer wont to sport them in the shade.
Could we, say they, suppose, that any would us cherish,
Which suffer (every day) the holiest things to perish?
Or to our daily want to minister supply?
These Iron Times breed none, that mind posterity.
Tis but in vain to tell what we before have been,
Or changes of the world that we in time have seen;
When, not devising how to spend our wealth with waste,
We to the savage swine let fall our larding mast.
But now, alas! ourselves we have not to sustain,
Nor can our tops suffice to shield our roots from rain;
Jove's oak, the warlike ash, vein'd elm, the softer beech,
Short hazel, maple plain, light asp, the bending wych,
Tough holly, and smooth birch, must altogether burn,
What should the builder serve, supplies the forger's turn;
When under public good base private gain takes hold,
And we, poor woful woods, to ruin lastly sold."

Polyolbion, Song xvii.

The relics of the iron trade during this century are very abundant, particularly andirons, of almost every imaginable pattern. The example (Fig. 23), which the writer lately purchased of a dealer in old iron at Lewes, is ornamented with the

Fig. 23.

Fig. 24.

arms of the family of Thatcher, and was probably cast for the hall of their fine old mansion, Priesthawes, in the parish of Westham. Fig. 24 is one of a pair in the possession of Mr. William Harvey.* The upper portion of the andiron is a *demy* human figure, in the costume of temp. James I., holding a tobacco-pipe in the

* The writer avails himself of this opportunity of acknowledging the kind assistance of Mr. Harvey, in calling his attention to the Burwash slab, and to many of the other productions of the Sussex furnaces, which illustrate this essay.

right hand, and in the left a jug or tankard. The bird on the shield is perhaps intended for a phœnix. The columnar andiron (which may belong to the close of the preceding century) is at Hammond's Place, Clayton, the property of Colonel Elwood (Fig. 25). This house was a seat of the Michelbornes, but the initials I. T. upon the andirons prove them to have belonged to some other family; perhaps the Turners of Old Land, in the same district. The next (Fig. 26), belonging to Mr. Hassell, of Waldron, is a remarkably clean and delicate piece of casting. It bears the date of 1640, and a coat of arms, which the writer has not been able to appropriate. It is traditionally reported to have been cast in the parish of Waldron. A pair of monster andirons, of about the same date, is in the possession of Mr. A. Playsted, of Wadhurst. They (Fig. 27) are 39 inches in height, and their style is Egyptian. The heraldic bearing, which is much defaced, appears to be "a cross between four martlets."

Fig. 25.

Fig. 26.

Fig. 27.—Andiron formerly at High Town, Wadhurst.

The chimney-backs of the seventeenth century are likewise exceedingly various in point of design. Many of them exhibit the royal arms, and the arms of noble and other families belonging to the county; others, classical stories, as Venus and Adonis, the Thief and Dog, from Æsop, &c.; some are ornamented with Scripture histories, particularly Abraham offering up Isaac, the Queen of Sheba, Christ and the woman of Samaria, &c.; and some with designs of a much more objectionable character. On a back at Maresfield is an equestrian figure of Charles I., with the initials C. R.; and Mr. Ashby of East Dean possesses a very curious one, adorned with an oak tree bearing acorns, and the same initials. Among the branches are three crowns, and on a scroll surrounding the trunk, the words "THE ROYAL OAK" —allusive to the incident of Charles II., the possessor of three crowns, taking refuge in the oak at Boscobel.

From the early part of the seventeenth century, down to the extinction of the manufacture, our foundries produced numbers of monumental slabs, which are still remaining in the churches of Sussex and Surrey. At Wadhurst, there are no less than thirty examples, ranging between the years 1625 and 1799. The

inscriptions and armorial decorations are in general of very rude workmanship, and, as the slabs lie upon the pavement of the nave and aisles, in somewhat inconveniently bold relief. The persons commemorated by them comprise individuals of the families of Bucher, Porter, Fowle, Dunmoll, Barham, Luck, Atwells, Braban, Holland, Saunders, Benge, and Playsted, many of whom were connected with the trade in this parish.

Fig. 28, of the slab of John Barham, a distinguished iron-master, represents one of the most interesting of the series.

In 1643, after the taking of Chichester and Arundel by the Parliament's forces, the iron-works belonging to the crown and to royalists, in the western division of Sussex, were destroyed by a detachment of the army commanded by Sir William Waller.*

Fig. 28.—Cast-iron Monumental Slab, Wadhurst Church.

The mode of making iron in Sussex in the seventeenth century is detailed by John Ray, the celebrated naturalist, in two papers appended to his *Collection of English Words*. "This account of the whole process of the iron-work," he says, "I had from one of the chief iron-masters of Sussex, my honoured friend, Walter Burrell, of Cuckfield, Esq., deceased." The particulars of the *modus operandi* of the manufacture, furnished from so authentic a source, are of sufficient value to warrant their introduction in this place.

"THE MANNER OF THE IRON-WORK AT THE FURNACE.

"The iron-mine lies sometimes deeper, sometimes shallower, in the earth, from four to forty [feet] and upward.

"There are several sorts of mine, some hard, some gentle, some rich, some coarser. The iron-masters always mix different sorts of mine together, otherwise they will not melt to advantage.

"When the mine is brought in, they take small-coal [charcoal] and lay a row of it, and upon that a row of mine, and so alternately S.S.S., one above another, and setting the coals on fire, therewith burn the mine.

"The use of this burning is to mollify it, that so it may be broke in small pieces; otherwise, if it should be put into the furnace as it comes out of the earth, it would not melt, but come away whole.

"Care also must be taken that it be not too much burned, for then it will loop, i.e. melt and run together in a mass. After it is burnt, they beat it into small pieces with an iron sledge, and then put it into the furnace (which is before charged with coals), casting it upon the top of the coals, where it melts and falls into the hearth, in the space of about twelve hours, more or less, and then it runs into a sow.

"The hearth, or bottom of the furnace, is made of sandstone, and the sides round, to the height of a yard, or thereabout; the rest of the furnace is lined up to the top with brick.

"When they begin upon a new furnace, they put fire for a day or two before they begin to blow.

"Then they blow gently and encrease by degrees 'till they come to the height, in ten weeks or more.

* Dallaway's *Western Sussex*.

"Every six days they call a "founday," in which space they make eight tun of iron, if you divide the whole sum of iron made by the foundays: for at first they make less in a founday, at last more.

"The hearth by the force of the fire, continually blown, grows wider and wider, so that at first it contains so much as will make a sow of six or seven hundred pound weight; at last it will contain so much as will make a sow of two thousand pound. The lesser pieces, of one thousand pound, or under, they call pigs.

"Of twenty-four loads of coals, they expect eight tun of sows: to every load of coals, which consists of eleven quarters, they put a load of mine, which contains eighteen bushels.

"A hearth ordinarily, if made of good stone, will last forty foundays, that is forty weeks, during which time the fire is never let go out. They never blow twice upon one hearth, though they go upon it not above five or six foundays.

"The cinder, like scum, swims upon the melted metal in the hearth, and is let out once or twice before a sow is cast.

"THE MANNER OF WORKING THE IRON AT THE FORGE OR HAMMER.

"In every forge or "hammer" there are two fires at least; the one they call the "finery," the other the "chafery."

"At the finery, by the working of the hammer, they bring it into "blooms" and "anconies," thus:

"The sow they, at first, roll into the fire, and melt off a piece of about three-fourths of a hundredweight, which, so soon as it is broken off, is called a "loop."

"This "loop" they take out with their shingling-tongs, and beat it with iron sledges upon an iron plate near the fire, that so it may not fall in pieces, but be in a capacity to be carried under the hammer. Under which they, then removing it, and drawing a little water, beat it with the hammer very gently, which forces cinder and dross out of the matter; afterwards, by degrees, drawing more water, they beat it thicker and stronger 'till they bring it to a "bloom," which is a four-square mass of about two feet long. This operation they call "shingling the loop."

"This done, they immediately return it to the finery again, and after two or three heats and workings, they bring it to an "ancony," the figure whereof is, in the middle, a bar about three feet long, of that shape they intend the whole bar to be made of it; at both ends a square piece left rough to be wrought at the chafery.*

"*Note.* At the finery three load of the biggest coals go to make one tun of iron.

"At the chafery they only draw out the two ends suitable to what was drawn out at the finery in the middle, and so finish the bar.

"*Note* 1. One load of the smaller coals will draw out one tun of iron at the chafery.

"2. They expect that one man and a boy at the finery should make two tuns of iron in a week: two men at the chafery should take up, i.e. make or work, five or six tun in a week.

"3. If into the hearth where they work the iron sows (whether in the chafery or the finery) you cast upon the iron a piece of brass, it will hinder the metal from working, causing it to spatter about, so that it cannot be brought into a solid piece."†

* The definition of "ancony" given in this paragraph is adopted by Bailey in his *Dictionary* (folio, 1730). In common with several terms employed in anatomy and architecture, it seems to be derived from the Greek word ἄγκων.

† Ray's *English Words* not generally used (originally published in 1672), 4th edition, printed in 1768, page 134, et seq.

An interesting relic of the manufacture is preserved at Howbourne, in the parish of Buxted. This the old "hammer-post" (Fig. 29), which exists *in situ* near the extremity of the once extensive but now drained pond. It is formed of an oak tree, and if not wantonly injured will stand for many years longer. Its height above ground is 9½ feet.

The greatest existing remains of Sussex iron are the balustrades which surround St. Paul's Cathedral. They were cast at Lamberhurst furnace, and their weight, including the seven gates, is above 200 tons. Their cost, according to the account-books kept at the furnace, was £11,202 0*s.* 6*d.** It may be mentioned that the annual consumption of wood at this furnace was about 200,000 cords! This establishment was subsequently called Gloucester Furnace, in honour of its having received a visit from the Princess (afterwards Queen) Anne, and the Duke of Gloucester.

If we may credit the general report of the parish, the cannon cast at Gloucester Furnace were not always employed for the use of the British navy, but were conveyed by smugglers to the coast, and there shipped for the service of French privateers, in the war then waged against England. This villany was detected, and the parties engaged in it were fined to a large amount. The government contracts were of course withdrawn; and from this period we may date the decline of these works.

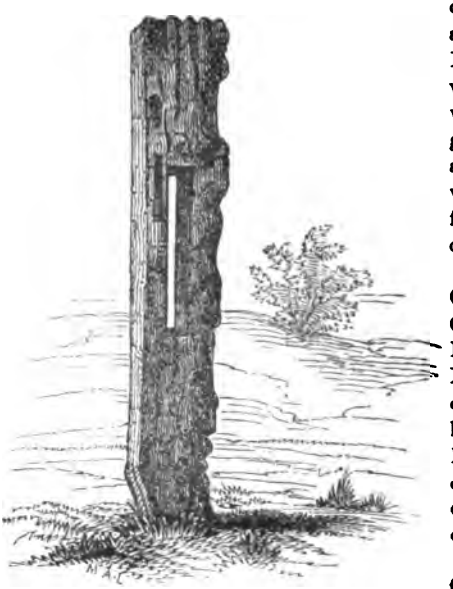

Fig. 29.

The iron-founders to King Charles II. were Mr. Alexander Courthope, of Horsmonden, co. Kent, and Mr. George Brown, of Buckland, co. Surrey: their foundries were at Ashburnham, Hawkhurst, Horsmonden, Barden, and Embden. Their correspondence, contracts with the commissioners of ordnance, &c., are in the possession of Mr. G. Courthope, of Whiligh.†

The manufacture continued to flourish with almost unabated vigour through the seventeenth century, and even in 1724 it was considered the chief interest of the county. In that year was published Budgen's Map of Sussex, a very useful document, as showing the sites of the still existing works. The ornaments surrounding the title of it consist of emblems of the trade, Vulcan with Venus and Cupid, Cyclops at the anvil and forge, &c.

Besides the illicit exportation of cannon above-mentioned, much heavy ordnance was shipped in the eighteenth century from the ports of Rye and Newhaven. Some seems to have been sent to our Asiatic colonies. When the late Major Fuller entered on his first campaign in India he found with mingled pleasure and surprise some of the old artillery there inscribed with the name of his native village "Heathfield!"

* *Topog. Libr. Sussex.* † Ex inf. Mr. W. Courthope, Rouge Croix.

We owe many of our finest sheets of water to the iron manufacture. In other instances, the meadows which were converted into "ponds and pools," have again been drained and restored to their former use, or appropriated as hop-gardens and osier beds. The sites of many of the "hammers" are now occupied by corn-mills.

In choosing sites for the works, our iron-masters of course sought spots which were at once contiguous to the beds of ore and to some convenient water power. The places chosen for artifical ponds were generally the vales through which streams and rivulets flowed. Across these were thrown great dams of earth, usually known as "pond-bays," with a convenient outlet of masonry for the supply of water, by means of which the wheel connected with the machinery of the "hammer" or the furnace was set in motion. A valley of moderate width was generally selected, as the narrow ravine and the broad level were equally objectionable, the former requiring too lofty, and the latter too long and expensive a pond-bay. All the Sussex rivers and their tributary streams within the first few miles of their course, are well adapted by nature for this useful purpose.

Upon the "decline and fall" of the trade few words are necessary. The amazing consumption of wood rendered the production of iron in this district more expensive than in those localities where the coal-mines and the ferruginous strata are in close proximity to each other. Upon Sir Roderic I. Murchison's authority, our Wealds still contain a much greater quantity of iron-ore, and that of richer quality, than many of the coal-fields of England; but for the reason alluded to, competition with those districts was hopeless. In spite, however, of the invention of "charking" sea-coal, alluded to as a desideratum by Fuller,* Sussex still maintained its position as a seat of the iron trade long after the establishment of that process;† and many families were enriched by the alchemy of transmuting iron to gold so lately as the middle of the last century. Conspicuous among these was that of Legas, one of whose members, John Legas, gent., "by his industry and diligence in the iron-works of this county, acquired a handsome fortune, with great credit and reputation. He died the 22d May, 1752, aged 62 years."‡ Even in the days of our grandfathers, cannon continued to be cast in some places, and the great hammer's "occuption" was not wholly "gone."§ By degrees, however, the glare of the furnace faded, the din of the hammer was hushed, the last blast was blown, and the wood-nymphs, after a long exile, returned in peace to their beloved retreats! Farnhurst, in western, and Ashburnham, in eastern Sussex, witnessed the total extinction of the manufacture.

The day may not be far distant when Sussex iron shall again be called into use. If anthracite fuel were brought to the south coast, and some of the richer veins of ore near the eastern extremity of the country were re-opened, it is calculated that the smelting might be advantageously and profitably carried on here. Within the last few years, the attention of several gentlemen, practically connected with the iron trade in distant parts of the island, has been directed to this subject.

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* *Worthies*, vol. iii, page 53, edition 1840.

† So recently as 1754, it appears that a Staffordshire ironmaster could profitably engage in the manufacture of Sussex iron; since in that year Sir Whistler Webster, Bart., of Battel Abbey, let his Robertsbridge furnace to a Mr. John Churchill, of Hints, co. Stafford. The iron of the south, wrought with charcoal, was probably found serviceable for mixing with the pit-coal iron of the lessee's home manufacture.

‡ Mon. Inscr. in Wadhurst Church.

§ From parliamentary papers quoted in the *Encyclopædia Britannica*, it appears that in 1740 there were 59 furnaces in England, of which 10 were in Sussex. In 1788, there were 77, only 2 of which were in Sussex. In 1796, the total was, for England 104, for Sussex *one*.

rank they acquired by their iron-works. The pond, whose waters impelled the machinery, still remains, and is about 20 acres in extent. A flour-mill, the property of Mr. R. Reeves, occupies the site, and here probably stood the mill, mentioned in Doomsday Book, which was valued, with the miller, at 4s. per annum.

Great quantities of cinders occur in the woods in the northern part of the parish, and among them pottery, presumed to be Roman, has been discovered. Norden mentions the Dyker (Dicker), principally in this parish, as one of the districts which had been disafforested by the iron-works of the vicinity.

Chithurst.—There is a hammer-pond near Coppet Hall, ½ mile north of the church.

Cuckfield.—The Burrels had great iron-works in this and the adjacent parishes. *Vide* Ray's account of the manufacture.*

Dallington.—The destruction of the once extensive Chase of Dallington, formerly belonging to the Pelhams, is attributable to the iron-works. The Ashburnham works extended into this parish.

Easebourne.—There were works on the Cowdray estate, and many chimney-backs in the farm-houses belonging to it still bear the Montague arms.

The sand in this district is so impregnated with iron, that if a common handkerchief be shaken over with it and then exposed to a shower of rain, it will be found to be covered with thousands of minute iron-moulds.†

East Grinstead.—Hammerwood, in this parish, seems to have derived its name from some neighbouring "hammer."

Fernhurst.—A large foundry, "anciently established here," was carried on by the family of Butler (Dallaway.). It was employed by government, about 1770, for the casting of cannon. It was the last in the western division.

Fletching.—Traces of iron-works appear in this parish.

Framfield.—In the reign of Elizabeth, certain articles of inquiry, delivered to Richard Leche, concerning the consumption of wood by the iron-works in the manor of Framfield (which extends into several adjacent parishes), were answered as follows:—

"First, there are three iron-furnaces that have wood, and have wood most years of the common woods, and these are they, viz., Pounsley Furnace, Huborne Forge, and Huggett's Furnace.

"There is no iron-work that all the whole woods may be brought to it within 3 miles, not yet within 4 miles; but there are within 3 miles of some one of the woods these remaining works, viz., Pounsley Wood, Eching Wood, of Ralph Leg's Furnace, and two hammers in Pope's Furnace, Little Buckstod Hammer, Huborne Hammer, Huggett's Furnace, and Pounsley Furnace; and there is more within 3 miles of Langhurst Wood and Barnet Wood, John Frenche's Hammer, and Waldron Furnace" (Horsfield—who does not mention whence he obtained the document).

Poundsley Furnace was worked by the Hodgsons in the seventeenth century. On Little Streele farm is a "Cinder Field." Fields called the "Iron Latches" on Bentley farm, seem to point out sites of iron-works. This name is of frequent occurrence in the Weald.

Frant.—Vestiges of several iron-works still remain in this parish. Budgen's map shows a forge westward of Eridge Park. This probably belonged to Mr. H. Neville (also owner of iron-works at Mayfield), who was considered the chief and representative of the Sussex iron-masters in 1587.

There were also a furnace and a forge within the existing park pale; the furnace pond still remains. Steel Bridge, on the Rotherfield road, indicates another site of the manufacture.

* *Trans. Fed. Inst.*, vol. xiv., page 724. † Ex inf. Mr. Hasler Hollist.

Ashdowne Forest.—The only furnace shown for this district in Budgen's map is "New Furnace." The Roman works at Maresfield were immediately contiguous to the forest.

Balcombe.—Norden mentions this place in his enumerations of the woods destroyed by the furnaces. There is, near the railway tunnel, a place called Cinder Banks, consisting of an immense deposit of scoriæ.

Battel.—Budgen's map shows Beach Furnace, near Netherfield, in this parish. There were probably other works towards Sedlescombe. The public-house at Netherfield is called "The Gun," a somewhat common sign in the iron district.

Beckley.—The works were situated near the road leading to Brede. The cannon and chimney-backs made here were principally exported from Rye. From the information of Mr. W. Holloway, it appears that a person now living, aged 74, perfectly remembers having seen, when a boy, the hammer and bellows of Beckley furnace only remaining.

Bolney.—The ironstone in this parish is of excellent quality; and upon the surface the writer has observed fragments of the "iron-rag," or pudding-stone, which had been exposed by the operation of the plough. Several large and beautiful sheets of water remain upon the presumed sites of the iron-mills; and Colwood or Coalwood Street marks the locality of extensive charcoal-works for the use of the neighbouring furnaces.

Brede.—The furnace here belonged, in the seventeenth century, to the Sackvilles, and afterwards to Mr. John Browne. This gentleman, about 1693, sold it to the Westerns of Essex. The works ceased about the year 1766, and a few years subsequently powder-mills were erected on the site. These existed till 1825, when the extensive ponds were drained.* A hop-garden occupies their bed. Immense quantities of cinders have been taken from this spot for the repair of the neighbouring roads, and many more still remain. The cannon and other articles made here were principally exported from Rye.

Brightling.—The works were carried on by the Fuller family† about the year 1700 and subsequently, at Brightling Forge. About a mile west of the Observatory stood Glazier's Forge. Socknersh Furnace was worked by the Collins family. Darval Furnace in, or bordering upon, this parish, was an extensive establishment.

Burwash.—Budgen's map mentions a forge here. On Goodsoal Farm was an air-furnace; and one of the woods is still called Furnace Wood.

Buxted.—The first iron cannon were cast here by Hogge and Baude.‡ Cannon-balls and other relics of the manufacture are frequently dug up near the "Hog-house," the residence of Hogge. Pope's Furnace, in the manor of Farmfield, was probably on the Hendall estate, in this parish, the residence of the Pope family. Huborne (now Howbourne) forge and hammer were also in this parish. The hammer-post, an interesting relic remains, *in situ*, near the extremity of the now drained pond, which occupied many acres, it is a ponderous oak tree (see Fig. 29), in remarkably fine preservation, and, if not wantonly injured, may stand for many years longer. Its height above ground is 9½ feet. Buxted Little Forge stood, the writer is told, upon the stream higher up than Howbourne.

Chailey.—Much ironstone has been excavated on the North Common. Cinder Hill, on the road to Newick, has vestiges of iron-works.

Chiddingly.—Stream Furnace, in this parish, was worked by the Frenches, who were yeomen in the sixteenth century, and gentry in the seventeenth. The latter

* Horsfield's *Sussex*, vol. i., page 514.

† They also worked Heathfield and Waldron Furnaces, etc.

‡ *Trans. Fcd. Inst.*, vol. xiv., page 711.

Horsham.—In the 6th year of Edward VI., 1552, a bill "to avoid iron-mills near Horsham, in Sussex," was brought into the House of Commons, February 23. March 16, it was ordered "that the suitors against the Horsham bill shall appear here to-morrow, with their counsel, at 8 o'clock." March 17, Mr. Foscoe, with his counsel, Mr. Catline, exhibited certain articles in writing against the bill. March 24. "Ordered, that the bill for Horsham be engrossed."*

Horsted Keynes.—The ponds which supplied the works still remain. "Furnace Field," "Furnace Wood," and "Forge Field" point out the localities. On Cinder Hill farm, great quantities of scoriæ have been dug; and many and-irons, and other articles preserved here, are traditionally reported to have been manufactured in the parish.

Ifield.—The site of the corn-mill at this place was formerly occupied by iron-works, where government ordnance was cast. They were destroyed by a detachment of Sir William Waller's troops in 1643, after the siege of Arundel; and were probably not rebuilt, as the old flour-mill was erected in 1683. The large hammer-ponds still remain.

Kirdford.—Norden mentions the destruction of woods at Kirdford, and at Ebernowe, also in this parish, by the furnaces. In the 'Customs of Schillinglee' (Shillinglee, in Kirdford), 1608, it is stated that "one Blackwell hath lately demised there certain iron-workes" (Dallaway). The ordnance map shows the site of a furnace at Shillinglee. At Ebernoe, the property of the Rev. J. Peachey, are many traces of iron-works. Cinders from the ancient pond are still used for the making of roads. "There is also a great quantity of coarse, vitreous matter from the glass-works, which seem to have been carried on simultaneously with the iron-furnaces in this part of the Weald."† At Barkfold, in this parish, there is a large hammer-pond.

Lamberhurst.—Gloucester Furnace, the largest iron manufactory in Sussex, was principally in this parish, though partly in Wadhurst. Its occupiers were residents in Wadhurst, and intimately connected with that parish. Three centuries since, it was worked by the Barhams, of Butts. (See under *Wadhurst.*) Mr. William Benge, of Faircrouch, in Wadhurst, rebuilt the works, and made them the most extensive of any in this part of the kingdom. Just at the time of their completion, they were honoured with a visit from the Princess (afterwards Queen) Anne and the Duke of Gloucester, who were sojourning at Tunbridge Wells; from which circumstance the name was derived. The undertaking was not successful to Mr. Benge, who had no sooner brought it to perfection than he failed.‡ The property then passed into the hands of Mr. Gott, and was let to Messrs. Legas & Harrison, who carried on the works with great vigour and success. Cannon were cast here for the service of the navy. Mr. Legas amassed a fortune to the amount, it is said, of £30,000, and died in 1752. He was succeeded by Mr. Richard Tapsell, who had married his niece. This gentleman sunk the money acquired by his uncle, became a bankrupt in 1765, and died in indigence about 12 years after. He was the last ironfounder connected with Wadhurst. The foundations of the furnace are still traceable, and near them is the proof-bank. The soil, for some distant round, abounds with cinders.

If we may credit the general report of the parish, the cannon cast at Gloucester Furnace were not always employed for the use of the British navy, but were

* *Journ. H. Com.*, vol. i., page 18 *et seq.*

† Ex inf. Mr. A. E. Knox, author of a very interesting contribution to the natural history of the county.—*Ornithological Rambles in Sussex*, London, 1849.

‡ The Kemps, of Great Pell, in Wadhurst, were founders here at some period in the early part of the eighteenth century.

conveyed by smugglers to the coast, and there shipped for the service of French privateers, in the war then waged against England. This villany was detected, and the parties engaged in it were fined to a large amount. The government contracts were of course withdrawn; and from this period we may date the decline of the works.*

Linchmere.—On the land of Mr. Hasler Hollist, in this parish, and about 3 miles south-west of Haslemere, there are considerable vestiges of iron-works. There are several acres of slag or cinders, and an osier bed occupies the place of the head of water, by means of which the forges were worked. Some good masonry, by which the water was confined and directed, still remains. The works here were among the last in the western division which experienced the impossibility of competing with the coal-producing districts of the North, and were not abandoned until the year 1776.†

Lindfield.—At Freshfield, in this parish, is a "Hammer Wood," probably indicating the site of an iron-work.

Lynch.—There were works here as early as 1342 (Nonæ).

Maresfield.—Roman iron-works at Old Land. Maresfield Forge, according to Budgen's map, was at work in 1724, and probably much later. Park Forge was situated about ½ mile westward of the church, and Old Forge upwards of a mile north-east of it.

Mayfield.—This parish was famous for its iron. There were considerable works upon the archiepiscopal estate at an early period. At the palace are several interesting relics of the manufacture, particularly the massive iron hand-rail of the grand staircase. The hammer, anvil, and tongs of St. Dunstan (see Figs. 7, 8, and 9), preserved here, seem to refer as much to the iron-trade, so famous in these parts, as to the alleged proficiency of the saint in the craft of a blacksmith. The anvil and tongs are of no great antiquity, but the hammer, with its iron handle, may be considered a medieval relic. Traces of the iron-works are still visible on the estate; and here, in all probability, were made the copings of Rochester bridge, presented to that city early in the sixteenth century by Archbishop Warham.‡ In an old map of the estate, yet extant, the 3 ponds for the use of these works measure respectively 3a. 1r. 4p.; 3a. 3r. 6p.; and 1a. 3r.

At Hawksden, in Bibleham quarter, there was a forge worked by the Morleys of Glynde. Mr. Thomas Morley, who died in 1558, worked an iron-mill and a furnace at that place, from which his daughter's jointure was levied. His great-grandson, Mr. Herbert Morley, the regicide, died possessed of these works, which descended to his sons, There was also a forge at Bibleham, in the same quarter.

The family of Baker, who ranked high as iron-masters, worked Bungehurst Furnace and Forge, and many others in this vicinity. They were originally of Battel, and are believed to have removed hither (about the beginning of the seventeenth century) for the purpose of carrying on the iron trade.§ They also had extensive works in Withyham, where they possessed land, temp. Henry VIII., and subsequently.

Huggett's Furnace is in the western district of this parish.

Coushossly Furnace, upon Stonehouse Farm, on the boundary stream between this parish and Wadhurst, belonged to the Penkherst family, and afterwards to the Dykes. It was at work in 1707. Cinder-heaps and other traces of works are visible on the Lower-House estate, the property of the Bakers, and on the farms called Twits and Merriams, in Five-ash quarter. ‖

* Ex inf. Mr. W. Courthope, Rouge Croix. † Ex inf. Mr. Hasler Hollist.
‡ Ex inf. Mr. W. Courthope, Rouge Croix. § Ex inf. Mr. J. B. Baker, a descendant.
‖ Ex. inf. Mr. W. Courthope.

Newick.—A quantity of cinders has been found in this parish, and there is a tradition of iron-works having been carried on near Fonthill, at the foot of which there was a great pond, on land now the property of Mr. W. H. Blaauw.

North Chapel.—A government charcoal manufactory was carried on here not many years since. At Frith, about three quarters of a mile north-east of the village, is a farm called Furnace House, with traces of a large furnace pond.* A nonagenarian resident remembers having been employed, in his youth, in the removal of the masonry connected with the pond on the site of the works.

Penhurst.—A considerable furnace.

Petworth.—Norden mentions "Petworth Parkes" among the "famous woods" devoured by the furnaces. There is a string of ponds in the northern division of the park (known as the "Stag Park"), on which anciently stood iron-works. Some of them have been drained and planted with osiers; others remain as fish-ponds. "The Minns," mentioned by Norden, is a wild, though partially enclosed, district, about 4 miles north-east of Petworth, and is now called "The Menns."

Rotherfield.—Many traces of iron-works. Hamsell Forge was worked by the Bakers. The Fowles were great iron-masters, and are presumed to have had works upon their estate at Welches, in this parish. At Brookhouse, there are cinder-banks.

Salehurst.—There were great iron and steel-works at Robertsbridge Abbey, already mentioned. In 1623, Robert Sidney, Earl of Leicester, assigned a lease of Udiham iron-house, in the manor of Robertsbridge, to John Culpeper and Henry English, with power to dig for iron in any of his lordship's lands in Salehurst, Ewhurst, Watlinge, and Watlington. In 1707, Elizabeth, Countess-dowager of Leicester, and John Sidney, her son, Earl of Leicester, leased the Robertsbridge Furnace for 11 years, to Thomas Snepp, sen., and Thomas Snepp, the younger, his son and heir.†

The cannon cast at Robertsbridge were floated down the Rother to Rye. In order to effect this, there were put into the river "shuts," a contrivance something in the nature of locks. When the bed of the Rother from Rye to Bodiham was cleansed, a few years ago, several of the remains of these shuts were brought to light, and removed.‡

St. Leonard's Forest.§—The works here were the most considerable in West Sussex. In the 44th year of Elizabeth, the whole forest was leased by the Crown to Sir John Caryll. "In this lease, the various forges, and all the instruments belonging to them, are enumerated" (Cartwright). They were afterwards employed "for military stores for the use of government, and so remained till 1643, when Chichester and Arundel were taken by Sir William Waller. A part of his army was dispatched for the purpose of totally destroying these and other iron-works belonging to the Crown, or to royalists, which have never since been restored" (Dallaway).

There are many traces of the works remaining, particularly extensive hammer-ponds and cinder-beds, on the southern borders of the forest.

Sedlescombe.—Traces of works carried on in this parish in Roman times. In the seventeenth century, the Farndens of Brickwall were great iron-masters. A coheiress married Mr. John Baker, of Mayfield, who died in 1723, and by whose family the works were afterwards carried forward. In the church is a cast-iron slab for the family of Bishop of Great Sanders. These slabs generally, if not uniformly, indicate iron-masters.

* Ex inf. Mr. A. E. Knox. † Thorpe's *Battel Abbey Deeds*, pages 201-202.
‡ Ex inf. Mr. W. Holloway. § *Trans. Fed. Inst.*, vol. xiv., page 724.

Shipley.—A large hammer-pond still remains at Bayntons in Shipley. The works here are presumed to have belonged to the Apsleys, of Apsley, in Thakeham.* The initials I. A. (for John Apsley?) occur upon many articles of Sussex manufacture. At Apsley House, there was, a few years since, a massive pair of andirons so marked, and among the chimney-backs produced by the same eminent iron-master are two very singular specimens, one dated 1582; the other, which was brought from this locality, is now in the possession of Captain Richardson, of Sutton Hurst. It is ornamented with the badge and supporters of Queen Elizabeth, and the legend, "THES . IS . FOR . IAMES . HIDE . AND . ION . HIS . MIF . 1582" (see Fig. 19.). It may perhaps have been a wedding present. These and many other examples of Sussex iron are stamped with the fleur-de-lis, which leads to the supposition that Frenchmen were much employed in our foundries. Knepp Pond, the largest piece of water in Sussex, was, according to the Rev. E. Turner, formerly a hammer-pond.

Slaugham.—The extensive works which existed in this parish are commemorated by the names of Hammer-pond, Furnace-pond, and Cinder-bank, still remaining.† The Covert family were great iron-masters.

Slindfold.—About 1½ miles north of this village is a place called Furnace Farm.‡

Tvcehurst.—Several vestiges; particularly traces of great ponds, and a farm called "Cinder-banks."

Twineham.—Iron-works are said to have existed here, although (as in the case of several other parishes) the writer is unprepared with any other evidence than that of common report.

Wadhurst.—This parish was especially celebrated for its iron-works. The following particulars relating to them have been obligingly communicated by Mr. William Courthope, Rouge Croix:

At Riverhall, in Faircrouch quarter, there were a furnace and a forge worked by the Fowles, a family of considerable note,§ whose prosperity rose and fell with the iron manufacture. Nicholas Fowle, who carried on these works, built in 1591 the fine mansion of Riverhall, which still exhibits traces of its former grandeur. His son, William Fowle, had a grant of free-warren from King James, over his numerous manors and lands in Wadhurst, Frant, Rotherfield, and Mayfield. The fourth in descent, and heir male of this personage, left Riverhall, and kept the turnpike-gate in Wadhurst. His grandson, Nicholas Fowle, a day-labourer, emigrated to America in 1839, with his son, John Fowle, a wheelwright, and a numerous young family, carrying with them as a family relic, the royal grant of free-warren given to their ancestor.

Brookland Forge and Ferredge Forge, on the borders of Frant, at or near Bartley Mill, or Little Shoesmiths, were worked by the Barhams of Butts, and Shoesmiths. Mr. John Barham of Butts, in Wadhurst, second son of a younger son of Mr. Henry Barham, lord of Barham, etc., co. Kent, a descendant (according to the Kentish historian and genealogist, Philipot) from Robert de Berham, son of Richard Fitz-Urse, and brother of the murderer of Thomas à Becket, was the founder of several branches of the Barhams inhabiting the mansions of Great Butts and Shoesmiths, the former of which has disappeared, and been replaced by a miserable little house. His descendant, Mr. John Barham, resided there till about 1713, when he sold the remnants of his paternal

* Ex inf. Mr. P. J. Martin.

† Ex inf. Mr. Thomas Wells. ‡ Ex inf. Mr. [illegible]

§ They were descended from a brother of Barth[illegible]tead, last prior of St. Mary Overie, in Southwark.

inheritance He died in obscurity in 1732, aged 75. Mr. John Barham, grandson of the above-named Mr. John Barham of Great Butts, erected or rebuilt, about 1630, the beautifully-situated and spacious mansion of Shoesmiths, and worked Bartley Mill and Brookland Forges. (See his monumental slab, Fig. 28). His grandson was high sheriff of the county, the 14th year of William III, but at his decease his family fell into obscurity.

Scragoak works were formerly carried on by the Mansers, and afterwards by the Barhams; and Snape Furnace, the property of the Barhams, was worked by the Culpeper family about the middle of the seventeenth century. David Barham built the greater portion of the present house at Snape about 1617. He died in 1643, and is interred in the south aisle of Wadhurst Church, beneath an iron slab of very curious workmanship. This estate afterwards passed to the Barhams of Scragoak, who worked the furnace there, and this line of the Barhams terminated with Nicholas Barham, who died in the workhouse in 1788, aged 82. The representative of these once distinguished families, now resident at Wadhurst, is Nicholas Barham, a wheelwright.

The family of Maunser, who were also iron-masters in Wadhurst, used Scragoak Furnace in the early part of the seventeenth century. Their residence was at High Town, which, upon the death of Mr. Nicholas Maunser in 1679, passed into other hands.

Gloucester Furnace was partly in this parish, but principally in Lamberhurst.

Waldron.—Extensive works were carried on in this parish by the Fuller family, who are believed to have materially enriched themselves by them. A descendant, the late Mr. John Fuller, of Rose Hill, in Brightling, adopted, in allusion to that circumstance, the motto, *Carbone et forcipibus.* It is scarcely necessary to confute the foolish tradition of the vicinity, that the founder of this respectable family gained his wealth by hawking nails about the county of Sussex upon the backs of donkeys! as the authentic family pedigree of the Fullers commences early in the sixteenth century with the name of John Fulwer or Fuller, citizen of London.

The furnace here was at work in the last century, and the neighbourhood abounds with specimens of its productions. Small chimney-backs, embellished with the lion of England, and the national badges of the rose, thistle, etc., so common in farmhouses and cottages for miles round, were cast at these works.

Warbleton.—The site of Richard Woodman's works is still pointed out. Cralle Furnace and Forge, upon the same stream which supplied Heathfield Furnace, belonged to the family of Cheney. Near Beeston's Farm was a steel forge. Adjacent to Rushlake Green is a field called "Furnace Field."

Westfield.—Roman coins have been found among cinders in this parish.

West Hothly.—There was a furnace in this parish (Horsfield).

Wisborough Green.—There was a furnace at Pallingham Farm in this parish. The pond connected with it was very large, but it is now drained and converted into a meadow of unusual fertility.

Withyham.—The Baker family, who had possessions here as early as temp. Henry VIII., were owners of Stoneland in the seventeenth century, and had iron-works, the machinery of which was impelled by a chain of ponds still existing below the house.

Worth.—The works here were very considerable. A piece of water, called the Furnace-pond, is connected by a rivulet with another just over the boundary of the county of Surrey, called the Forge-pond, about half a mile distant. Cannon have been cast here and conveyed to London within the last 70 years.*

* Ex inf. Mr. W. Figg.

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EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil and Mechanical Engineers.

S.—Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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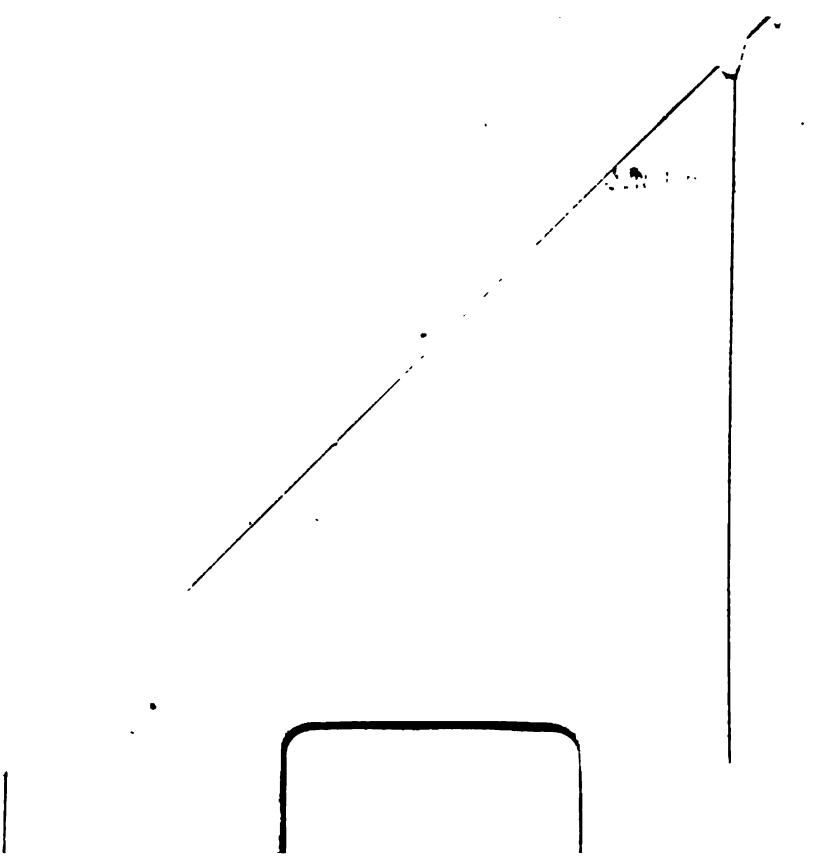
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